NORTH OF ENGLAND INSTITUTE OF MINING

AND MECHANICAL ENGINEERS.

TRANSACTIONS.

VOL. XXI.

1871-72.

NEWCASTLE-UPON-TYNE: A. REID, PRINTING COURT BUILDINGS, AKENSIDE HILL.

1872.

NEWCASTLE-UPON-TYNE:
ANDREW REID, PRINTING COURT BUILDINGS, AKENSIDE HILL.

CONTENTS OF VOL. XXI.

	PAGE
Report of Council	v
Finance Report	vii
Account of Subscriptions	viii
Treasurer's Account	x
General Account	xii
Patrons	xiii
Honorary and Life Members	xiv
Officers, 1872-73	xv
Members	xvi
Students	xxxiv
Subscribing Collieries	xxxvii
Rules	xxxviii
Barometer Readings, Appendix I.	End of Vol.
Patents, Appendix II.	End of Vol.
Address by the Dean of Durham on the Inauguration of the College of Physical Science	End of Vol.
Index	End of Vol.

GENERAL MEETINGS.

		PAGE
1871.		
Sept. 2.—	Election of Members, &c.	1
Oct. 7.—	Paper by Mr. Henry Lewis "On the Method of Working Coal by Longwall, at Annesley Colliery, Nottingham"	3
	Discussion on Mr. Smyth's Paper "On the Boring of Pit Shafts in Belgium	9
	Paper "On the Education of the Mining Engineer," by Mr. John Young	21
	Discussed	39
Dec. 2.—	Paper by Mr. Emerson Bainbridge "On the Difference between the Statical and Dynamical Pressure of Water Columns in Lifting Sets"	49
	Paper "On the Cornish Pumping Engine at Settlingstones," by Mr. F. W. Hall	59
	Report upon Experiments of Rivetting with Drilled and Punched Holes, and Hand and Power Rivetting	67
1872.		
Feb. 3.—	Paper by Mr. W. N. Taylor "On Air Compressing Machinery as applied to Underground Haulage, &c., at Ryhope Colliery" ...	73
	Discussed	80
	Alteration of Rule IV.	82
Mar. 2.—	Election of a Councillor in place of Mr. Hosking, deceased	83
	Paper "On the Scroll Drum," by Mr. George Fowler	85
	Discussion on Messrs. Bainbridge and Hall's Papers	91
	Discussion on Mr. Lewis' Paper "On Longwall Working at Annesley Colliery"	104

PAGE.

April 6.—Paper "On the Use of Air-vessels in Pumping Engines, and the means of replenishing them," by Mr. R B. Sanderson 115
Paper (No. 2) "On Pumping Water," by Mr. W. Waller 123
Discussed 155

May 4.—Paper "On Arrangements of Machinery adapted for Pumping Water in Dip Workings at the Kinneil Iron Works, at a distance from the Shaft," by Mr. Ralph Moore 159
Paper "On Ten Years' Mineral Statistics of the United Kingdom," by Mr. W. F. Howard 161
Paper "On the application of Machines, worked by Compressed Air in the Collieries of Sars-Longchamps and Bouvy, at Saint Vaast, in Belgium, by M. F. L. Cornet (translated by Mr. John Daglish) 199

July 2, 3, 4.—Joint Meeting with the Scottish and South Lancashire Engineers 221
Paper "On Geology in some of its Practical Aspects," by Professor David Page, LL.D. 241
Paper on the Carboniferous Limestone of South Durham and North Yorkshire, by Mr. William Cockburn... 251

Aug. 3.—Election of Officers, 1872–73 287
Discussion as to Re-printing Vols. III., IV., and V. 288
Proposed Incorporation of the Institute 289
Paper "On Mineral Oil as a Lubricant for Machinery," by Mr. I. J. Coleman 291
Paper "On a New and Improved Method of Screening and Loading Coals," by Mr. Robert Miller 295

Report.

The Council have much pleasure in being able to report on the continued prosperity of the Institute.

The number of new members added during the last year has been 106, making the total number 682. This is considerably in excess of the addition made in any former year, and more than twice that which took place on the occasion of the admission of Mechanical Engineers to the privilege of membership, and may be considered a flattering proof that the efforts of the Institute to advance the sciences of Mining and Mechanical Engineering and improve the general standard of the scientific education of the district are appreciated.

The persistent exertions made by the Institute from its very commencement to effect the establishment of a College of Science in Newcastle are too well known to the members to be alluded to at any length here. The Council trust that the recent success of these efforts has attracted the attention of the scientific portion of the inhabitants of the district, and it is with extreme satisfaction they remark that the extraordinary increase in the number of new members has taken place during the year that the College of Physical Science has been established, and they confidently anticipate that these kindred establishments, having one common aim, may mutually strengthen and assist each other.

The Wood Memorial Hall is now open, and forms a valuable addition to the Institute for increasing its sphere of usefulness. It is a very handsome building, suited to the requirements of the members, and the Council think it a matter of congratulation that the testimonial to the memory of Mr. Nicholas Wood, first President of the Institute, should have taken this form.

It is with deep regret the Council have to record the death of Mr. John Middleton, of Benton. This gentleman was one of the earliest members of the Institute, having been elected in 1853, and his loss will be keenly felt by all who knew him.

Mr. J. Hosking, a member of Council, and for upwards of twenty years associated with the firm of Messrs. Hawks, Crawshay and Co., has also died. This gentleman was connected with the works of the High Level Bridge, under the late Mr. Robert Stephenson, and invented a valuable form of valve for pumps. He was a man of varied information, and held in very high esteem as a Mechanical Engineer.

The members of the Institute have had the satisfaction of entertaining in Newcastle the members of the Institution of Engineers and Shipbuilders in Scotland, and the South Lancashire and Cheshire Coal Association. The number of gentlemen who responded to the invitation, and the expressions of satisfaction the Council continue to receive from those who attended, leave no doubt that the meetings of the 2nd, 3rd, and 4th July, 1872, in Newcastle, were a success. The best thanks of the Institute are due to the Committee who made the arrangements, and to the various gentlemen who so liberally contributed to the expenses. The Council also draw the attention of the members to the very great courtesy shown by the Mayor and Corporation of Newcastle, the Authorities of the University of Durham, the Professors of the College of Physical Science in Newcastle, the Literary and Philosophical and the Natural History Societies, the River Tyne Commissioners, and the various Coal Owners and Manufacturers in the neighbourhood, and have much pleasure in recording the thanks of the Institute to all who, by their attention, contributed so greatly to the success of the meetings.

The Council think they ought not to close this Report without alluding to the valuable services rendered to the Institute and the cause of education in the district by Mr. E. F. Boyd, whose term of office, as President, now expires. For many years he held the office of Treasurer, and to his care and attention may be traced the happy financial position the Institute now enjoys. It has been a most fortunate circumstance that this gentleman, who ever had at heart the work to which the Institute had devoted itself, should have ruled its councils at a time when liberal and active gentlemen were leading opinion in the University of Durham. Mr. Boyd will retire from the Presidency with the best wishes of the members, who will recollect, with pride and satisfaction, the work he has enabled them to do, and with an earnest desire on their part that he may be spared for many years to continue his exertions in the good work now commenced.

Finance Report.

Your Committee have pleasure in reporting that the income of the Institute for the year just past shows an increase as compared with that of the previous year of £167 18s. 10d.; the receipts for 1870-71, being £1437 11s. 8d., and for the year now past, £1605 10s. 6d. The expenditure has been £570 8s. 7d. above the income for the year. This includes an outlay of about £1,200 for the completion of the Wood Memorial Hall, the rooms under which are now let, and produce a rental of £50 per annum.

Signed on behalf of the Finance Committee,

LINDSAY WOOD.

DR. THE TREASURER IN ACCOUNT

				£	s.	d.
To 545 Old Members, as per List, 1871-2				1144	10	0
To 83 New Members				174	6	0
To 47 Old Students				49	7	0
To 2 Do. paid as Members				2	2	0
To 23 New Students				24	3	0
To 15 Subscribing Collieries				73	10	0
				1467	18	0
To Arrears, 1870-71, as per last Balance Sheet	198	9	0			
Deduct.						
Irrecoverable Arrears not inserted in 1871-2 List (Dead, Resigned, &c.)	80	17	0			
Actual Arrears to collect				117	12	0
Total Amount to collect, 1871-2				£1585	10	0

WITH SUBSCRIPTIONS, 1871-72. Cr.

	PAID.			UNPAID.		
	£	s.	d.	£	s.	d.
By 497 Old Members paid	1043	14	0			
By 2 Do. dead				4	4	0
By 5 Do. resigned				10	10	0
By – Do. struck off				,,	,,	,,
By 39 Do. unpaid				81	18	0
By – Do. paid as Students				,,	,,	,,
By 2 Do. "gone, no address"				4	4	0
545						
By 71 New Members paid	149	2	0			
By 12 Do. unpaid				25	4	0
83						
By 47 Old Students paid	49	7	0			
By 2 Do. paid as Members	2	2	0			
By – Do. gone	,,	,,	,,			
By – Do. resigned	,,	,,	,,			
49						
By 18 New Students paid	18	18	0			
By 5 Do. unpaid				5	5	0
By – Do. paid as Members	,,	,,	,,			
By 15 Subscribing Collieries	73	10	0			
	1336	13	0	131	5	0
By Members' Arrears	69	6	0	48	6	0
By Students' Arrears	,,	,,	,,	,,	,,	,,
	1405	19	0	179	11	0
				1405	19	0

Audited and Certified,
July 27th, 1872,
BENSON, ELAND, & CO.,
Public Accountants.

£1585 10 0

TREASURER IN ACCOUNT WITH THE NORTH OF ENGLAND

Dr. *For the Year ending*

1871.										£ s. d.	
July.	To Balance at Bank at this date									352 14 10	
	,, Balance in Secretary's hands									12 9 5	
	,, Balance in hands of Liquidators of District Bank									12 7 3	
	,, Bequest of the late R. Stephenson, Esq., invested on Mortgage of Northumberland Dock Rates									2000 0 0	
	,, Deposit at Lambton and Co.									500 0 0	
										2877 11 6	
	,, Interest on the above Bequest						£95 0 0				
	Less Income Tax						2 4 9				
							92 15 3				
	,, Interest on Deposit at Lambton's						4 6 3				
										97 1 6	
	,, Rent									50 0 0	
	,, Arrears of Subscriptions Received									69 6 0	
	,, Subscriptions for 1871–2 from 497 Old Members						£1043 14 0				
	,, Ditto ditto 71 New do.						149 2 0				
	,, Ditto ditto 47 Old Students						49 7 0				
	,, Ditto ditto 2 paid as Members						2 2 0				
	,, Ditto ditto 18 New Students						18 18 0				
							1263 3 0				
	,, Subscriptions from Collieries, viz.:—										
	Black Boy				£4 4 0						
	East Holywell				2 2 0						
	Haswell				4 4 0						
	Hetton				10 10 0						
	Kepier Grange				2 2 0						
	Lambton				10 10 0						
	Leasingthorne				2 2 0						
	Londonderry				10 10 0						
	North Hetton				6 6 0						
	Ryhope				4 4 0						
	Seghill				2 2 0						
	South Hetton and Murton ...				8 8 0						
	Stella				2 2 0						
	Westerton				2 2 0						
	Whitworth				2 2 0						
							73 10 0				
										1336 13 0	
	,, Sale of Publications per A. Reid						58 5 6				
	Less 10 per Cent. Commission						5 15 6				
										52 10 0	
										£4483 2 0	

INSTITUTE OF MINING AND MECHANICAL ENGINEERS.

August, 1872. CR.

				£	s.	d.
1872. By paid A. Reid, Publishing Account	£377	0	6			
„ Ditto Covers for Parts, &c.	6	9	6			
„ Ditto Binding and Sewing Volumes ...	11	1	0			
„ Ditto Postage Stamps	22	16	8			
„ Ditto Stationery and Circulars	65	2	4			
				482	10	0
„ Secretary's Postages and Sundries				67	12	10
„ Sundry Small Accounts				5	19	2
„ Travelling Expenses				5	0	9
„ Secretary's Salary				200	0	0
„ Assistant's do.				50	0	0
„ Reporter's do.				12	12	0
„ Howard for Wood Memorial Hall	£1055	0	3			
„ Less Received from Literary and Philosophical Society, Half Cost of Bridge	173	16	7			
				881	3	8
„ Furnishing, viz. :—						
Brumell, Hardware	0	10	6			
Safe	6	0	0			
Gas Fittings (Offices)	16	13	4			
Ditto (Hall)	67	8	6			
Moor, Office Furniture	39	12	6			
Gibson, Plumber	4	17	0			
Walker and Emley	5	5	0			
				140	6	10
„ Cook—Windows, Wood Memorial Hall				250	0	0
„ Rent				40	0	0
„ Fire Insurance				6	14	7
„ Coals				5	8	3
„ Subscription to Natural History Society				20	0	0
„ Present to Librarians at Literary and Philosophical Society...				7	10	0
„ Benson, Eland, and Co., Audit of Accounts				1	1	0
„ Cash in Secretary's hands				17	5	0
„ Balance in hands of Liquidators of District Bank				12	7	3
„ R. Stephenson, Esq., Bequest as per Contra				2000	0	0
„ Balance of Current Account at Bank				277	10	8
				£4483	2	0

Audited and certified,

July 27, 1872,

BENSON, ELAND, & Co.,

PUBLIC ACCOUNTANTS.

GENERAL STATEMENT, JULY, 1872.

Dr. | Cr.

Liabilities.	£	s.	d.
None ... ... :	,,	,,	,,
Capital	3853	6	5
	£3853	6	5

Assets.	£	s.	d.	£	s.	d.
By Balance of current Account at Bankers				277	10	8
,, Balance in hands of Liquidators of District Bank...				12	7	3
,, Amount invested on Mortgage of Northumberland Dock Rates (River Tyne Commissioners) ...				2000	0	0
,, Cash in Secretary's hands				17	5	0
Arrears of Subscriptions				179	11	0
Value of 310 Bound Vols. of Transactions...	162	15	0			
,, 2104 Sewed do. do. ...	946	16	0			
,, 6 Bound Reports on the Haulage of Coal	2	14	0			
,, 14 Sewed do. do. ...	4	7	6			
,, Sundry Plates and Sheets belonging Vol. XXI., unfinished at this date	250	0	0			
				1366	12	6
				£3853	6	5

Audited and certified,

July, 1872,

BENSON, ELAND, & Co.,

Public Accountants.

Patrons.

His Grace the DUKE OF NORTHUMBERLAND.
His Grace the DUKE OF CLEVELAND.
The Right Honourable the EARL OF LONSDALE.
The Right Honourable the EARL GREY.
The Right Honourable the EARL OF DURHAM.
The Right Honourable the EARL VANE.
The Right Honourable LORD WHARNCLIFFE.
The Right Honourable LORD RAVENSWORTH.
The Right Reverend the LORD BISHOP OF DURHAM.
The Very Reverend the DEAN AND CHAPTER OF DURHAM.
WENTWORTH B. BEAUMONT, Esq., M.P.

Honorary Members.

	Elected. Ordy.	Hon.
WILLIAM ALEXANDER, Esq., Inspector of Mines, Glasgow ...		1863
* JAMES P. BAKER, Esq., Inspector of Mines, Wolverhampton ...	1853	1866
LIONEL BROUGH, Esq., Inspector of Mines, Clifton, Bristol ...		1855
JOSEPH DICKINSON, Esq., Inspector of Mines, Manchester ...		1853
THOMAS EVANS, Esq., Inspector of Mines, Field Head House, Belper		1855.
PETER HIGSON, Esq., Inspector of Mines, 94, Cross Street, Manchester	1854	1856
* RALPH MOORE, Esq., Inspector of Mines, Glasgow		1866
* G. W. SOUTHERN, Esq., Inspector of Mines, 17, Wentworth Place, Newcastle-upon-Tyne	1854	1866
* THOMAS E. WALES, Esq., Inspector of Mines, Swansea	1855	1866
* FRANK N. WARDLE, Esq., Inspector of Mines, Wath-on-Dearne, near Rotherham	1864	1868
JAMES WILLIS, Esq., Inspector of Mines, 13, Old Elvet, Durham	1857	1871
THOMAS WYNNE, Esq., Inspector of Mines, Stone		1853
Sir GOLDSWORTHY GURNEY, Bude Castle, Cornwall		1853
CHARLES MORTON, Esq., Ex-Inspector of Mines		1853
WARINGTON W. SMYTH, Esq., 28, Jermyn Street, London ...		1869
The Very Rev. Dr. LAKE, Dean of Durham		
Prof. MARRECO, M.A., College of Physical Science, Newcastle...		1872
„ HERSCHEL, B.A., F.R.A.S., do. do. ...		1872
„ ALDIS, M.A., do. do. ...		1872
„ PAGE, LL.D., do. do. ...		1872
M. DE BOUREUILLE, Commander de la Légion d'Honneur, Conseiller d'état, Inspecteur General des Mines, Paris ...		1853
HERR R. VON CARNALL, Berghauptmann, Ritter, etc., Breslau Silesia, Prussia		1853
Dr. H. VON DECHEN, Berghauptmann, Ritter, etc., Bon am Rhine, Prussia		1853
M. THEOPHILE GUIBAL, School of Mines, Mons, Belgium ...		1870

Life Member.

	Ordy.	Life.
H. J. MORTON, Esq., Garforth House, Leeds, Yorkshire	1856	1861

* Honorary members during term of office only.

OFFICERS, 1872-73.

President.

Sir W. G. ARMSTRONG, C.B., LL.D., F.R.S., Jesmond, Newcastle-on-Tyne.

Vice-Presidents.

W. COCHRANE, Esq., Oakfield House, Coxlodge, Newcastle-on-Tyne.
JOHN DAGLISH, Esq., F.G.S., Tynemouth.
G. B. FORSTER, Esq., Backworth House, near Newcastle-on-Tyne.
JOHN MARLEY, Esq., Mining Offices, Darlington.
R. S. NEWALL, Esq., Ferndene, Gateshead.
A. L. STEAVENSON, Esq., Holywell, Durham.

Council.

T. J. BEWICK, Esq., Haydon Bridge, Newcastle-on-Tyne.
W. BOUCH, Esq., Shildon Works, Darlington.
W. BOYD, Esq., Spring Gardens Engine Works, Newcastle-on-Tyne.
T. CABRY, Esq., Blyth and Tyne Railway Offices, Newcastle-on-Tyne.
S. C. CRONE, Esq., Killingworth Colliery, near Newcastle-on-Tyne.
T. DOUGLAS, Esq., Peases' West Collieries, Darlington.
T. HAWTHORN, Esq., 74, Rye Hill, Newcastle-on-Tyne.
W. H. HEDLEY, Esq., Medomsley, Burnopfield, County of Durham.
R. HODGSON, Esq., Whitburn, near Sunderland.
T. G. HURST, Esq., Riding-Mill-on-Tyne.
HUBERT LAWS, Esq., Grainger Street West, Newcastle-on-Tyne.
D. P. MORISON, Esq., Collingwood Street, Newcastle-on-Tyne.
JAMES NELSON, Esq., King's House Engine Works, Sunderland.
W. A. POTTER, Esq., Cramlington House, Northumberland.
J. A. RAMSAY, Esq., Washington Colliery, County of Durham.
R. B. SANDERSON, Esq., Westgate Road, Newcastle-on-Tyne.
J. B. SIMPSON, Esq., Hedgefield House, Blaydon-on-Tyne.
JAMES WILLIS, Esq., 13, Old Elvet, Durham.

Ex-officio	E. F. BOYD, Esq., Moor House, near Durham. G. ELLIOT, Esq., M.P., Houghton Hall, Fence Houses. T. E. FORSTER, Esq., 7, Ellison Place, Newcastle-on-Tyne.	Past Presidents.
	I. L. BELL, Esq., Washington Hall, County of Durham. T. E. HARRISON, Esq., Central Station, Newcastle. LINDSAY WOOD, Esq., Hetton Hall, Fence Houses.	Retiring Vice-Presidents.

Secretary and Treasurer.

THEO. WOOD BUNNING, Newcastle-on-Tyne.

List of Members.

AUGUST, 1872.

		ELECTED.
1	Ackroyd, Thomas, Berkenshaw, Leeds	Mar. 7, 1867.
2	Adams, W., Severn House, Roath Road, Cardiff ...	1854.
3	Ainslie, Aymer, Iron Ore Master, Ulverstone	Aug. 7, 1869.
4	Aitken, Henry, Falkirk, N.B.	Mar. 2, 1865.
5	Allison, T., Belmont Mines, Guisbro'	Feb. 1, 1868.
6	Anderson, C. W., St. Hilda's Colliery, South Shields ...	Aug. 21, 1852.
7	Anderson, J., Solicitor, Newcastle-upon-Tyne	Oct. 1, 1863.
8	Anderson, William, Rainton Colliery, Fence Houses ...	Aug. 21, 1852.
9	Appleby, C. E., Reinshaw Colliery, near Chesterfield ...	Aug. 1, 1861.
10	Archbold, J. W. M., Murton Colliery, Fence Houses ...	Sept. 5, 1868.
11	Archer, T., Dunston Engine Works, Gateshead ...	July 2, 1872.
12	Arkless, John, Tantoby, Burnopfield	Nov. 7, 1868.
13	Armstrong, Sir W. G., C.B., LL.D., F.R.S., Jesmond, Newcastle-upon-Tyne ... ... (President)	May 3, 1866.
14	Armstrong, William, Pelaw House, Chester-le-Street ...	Aug. 21, 1852.
15	Armstrong, W. L., 5, Hawthorn Terrace, Newcastle ...	Mar. 3, 1864.
16	Armstrong, W., jun., Wingate, Co. Durham	April 7, 1867.
17	Ashwell, H., Anchor Colliery, Longton, No. Staffordshire	Mar. 6, 1862.
18	Asquith, T. W., Seaton Delaval Colliery, Northumberland	Feb. 2, 1867.
19	Attwood, C., Holywood House, Wolsingham, Darlington	May 7, 1857.
20	Aubrey, R. C., London and Merthyr Collieries, Kirwain, South Wales	Feb. 5, 1870.
21	Austin, C. D., 40, Mosley Street, Newcastle	July 2, 1872.
22	Bachke, A. S., Ytterven Mines, near Drontheim, Norway	Mar. 5, 1870.
23	Badger, A., M.E., 4, Bankshall Street, Calcutta ...	Nov. 5, 1870.
24	Bagnall, Thomas, jun., Grosmont Iron Works, near York	Mar. 6, 1862.
25	Bailes, John, Wingate Colliery, Ferryhill	Sept. 5, 1868.
26	Bailes, T., jun., 41, Lovaine Place, Newcastle-on-Tyne	Oct. 7, 1858.
27	Bailey, G., St. John's Colliery, Wakefield	June 5, 1869.

ELECTED.

28 Bailey, Samuel, The Pleck, Walsall, Staffordshire ... June 2, 1859.
29 Bailey, W. W., Kilburn, near Derby ... ... May 13, 1858.
30 Bainbridge, Emerson, Sheffield and Tinsley Coal Offices, Sheffield ... ... Dec. 3, 1863.
31 Balleny, C. D., Timber Merchant, Red Barns, Newcastle Feb. 4, 1871.
32 Barclay, A., Caledonian Foundry, Kilmarnock, N.B. ... Dec. 6, 1866.
33 Barkus, Wm., jun., Tynemouth... ... ... Aug. 21, 1852.
34 Barnes, T., Quay, Newcastle-on-Tyne ... ... Oct. 7, 1871.
35 Bartholomew, C., Doncaster, Yorkshire ... ... Aug. 5, 1853.
36 Bassett, A., Tredegar Mineral Estate Office, Cardiff ... 1854.
37 Bates, Matthew, Cyfarthfa Iron Works, Merthyr Tydvil Feb. 1, 1868.
38 Batey, John, Newbury Collieries, Coleford, Bath ... Dec. 5, 1868.
39 Beacher, E., Chapeltown, near Sheffield ... ... 1854.
40 Beanlands, A., M.A., North Bailey, Durham ... ... Mar. 7, 1867.
41 Bell, I. L., Washington, Washington Station, N.E. Railway ... ... (*Member of Council*) July 6, 1854.
42 Bell, John, Normanby Mines, Middlesbro'-on-Tees ... Oct. 1, 1857.
43 Bell, Thomas, Jesmond, Newcastle-upon-Tyne ... Sept. 3, 1870.
44 Bell, T. ... ... 1854.
45 Bell, T., jun., 2, Britannia Terrace, Saltburn-by-the-Sea Mar. 7, 1867.
46 Benson, T. W., 33, Bigg Market, Newcastle ... ... Aug. 2, 1866.
47 Berkley, C., Marley Hill Colliery, Gateshead ... ... Aug. 21, 1852.
48 Bewick, T. J., M. Inst. C.E., F.G S., Haydon Bridge, Northumberland ... ... (*Member of Council*) April 5, 1860.
49 Bidder, B. P., Duffryn Collieries, Neath, Glamorganshire May 2, 1867.
50 Bidder, S. P., Victoria Graving Docks, Victoria Docks, London ... ... Dec. 4, 1869.
51 Bigland, J., Bedford Lodge, Bishop Auckland ... June 4, 1857.
52 Binns, C., Claycross, Derbyshire ... ... July 6, 1854.
53 Biram, B., Peasely Cross Collieries, St. Helen's, Lancashire 1856.
54 Birkbeck, G. H., 34, Southampton Buildings, Chancery Lane, London ... . Dec. 7, 1867.
55 Black, James, jun., Ironfounder, South Shields ... Sept. 2, 1871.
56 Black, W., Hedworth Villa, South Shields ... ... April 2, 1870.
57 Blagburn, C., 3, St. Nicholas' Buildings, Newcastle ... Sept. 2, 1871.
58 Bolckow, H. W. F., Middlesbro'-on-Tees ... ... April 5, 1855.
59 Bolton, H. H., Newchurch Collieries, near Manchester Dec. 5, 1868.
60 Boot, J. T., M.E., The Orchards, Hucknall, Alfreton... April 1, 1871.
61 Booth, R. L., Medomsley, Burnopfield ... ... 1864.

ELECTED.

62 BOUCH, W., Shildon Works, Darlington (*Member of Council*) June 4, 1870.
63 Bourne, Peter, 39, Rodney Street, Liverpool .. ... 1854.
64 Bourne, S., West Cumberland Hematite Iron Works, Workington ... ... Aug. 21, 1852.
65 BOYD, E. F., Moor House, near Durham (PAST PRESIDENT Member of Council) Aug. 21, 1852.
66 BOYD, WM., Spring Gardens Engine Works, Newcastle (*Member of Council*) Feb. 2, 1867.
67 Boyd, Nelson, Carrickfergus, Ireland ... ... Mar. 3, 1864.
68 Breckon, J. R., Park Place, Sunderland ... ... Sept. 3, 1864.
69 Brettell, T., Mine Agent, Dudley, Worcestershire ... Nov. 3, 1866.
70 Briart, A., Ingénieur en chef des Charbonnages de Mariemont et de Bascoup, Mons ... ... Sept. 2, 1871.
71 Broadbent, J. C., The Heights, Rochdale ... ... Mar. 7, 1867.
72 Brogden, James, Tondû Iron and Coal Works, Bridgend, Glamorganshire ... ... 1861.
73 Brougham, the Hon. Wilfred, Brougham, Penrith ... May 6, 1871.
74 Brown, J. N., 56, Union Passage, New St., Birmingham 1861.
75 Brown, Ralph, Ryhope Colliery, Sunderland ... ... Oct. 1, 1863.
76 Brown, Thos. Forster, Guildhall Chambers, Cardiff ... 1861.
77 Browne, B. C., Assoc. M.I.C.E., North Ashfield House, Newcastle-on-Tyne ... ... Oct. 1, 1870.
78 Browne, W. R., Docks Engineers' Offices, Cumberland Row, Bristol ... ... May 6, 1871.
79 Bruton, W., M.E., Whitwood Collieries, near Normanton Feb. 6, 1869.
80 Brydon, J. F., Hematite Iron Works, Whitehaven ... Nov. 3, 1866.
81 Bryham, William, Rose Bridge, &c., Collieries, Wigan Aug. 1, 1861.
82 Bryham, W., jun., Douglas Bank Collieries, Wigan ... Aug. 3, 1865.
83 BUNNING, THEO. WOOD, Corbridge, Northumberland (*Secretary and Treasurer*) 1864.
84 Burn, James, 3, St. Vincent Street, Sunderland ... Aug. 2, 1866.
85 Burrows, James, Douglas Bank, Wigan, Lancashire ... May 2, 1867.

86 CABRY, J., Blyth and Tyne Railway Offices, Newcastle (*Member of Council*) Sept. 4, 1869.
87 Caldwell, George, Moss Hall Colliery, near Wigan ... Mar. 6, 1869.
88 Campbell, James, Stavely Works, Chesterfield... ... Aug. 3, 1865.
89 Carr, Charles, Cramlington, Newcastle-upon-Tyne ... Aug. 21, 1852.
90 Carr, Wm. Cochrane, Blaydon-on-Tyne ... ... Dec. 3, 1857.

ELECTED.

91 Carrington, T., jun., Field Head, near Sheffield ... Aug. 1, 1861.
92 Catron, J., Brancepeth Colliery Offices, Willington, Co. Durham ... ... Nov. 3, 1866.
93 Chadborn, B. T., Pinxton Collieries, Alfreton, Derbyshire 1864.
94 Chambers, A. M., Thorncliffe Iron Works, nr. Sheffield Mar. 6, 1869.
95 Chambers, H., Tinsley Collieries, Sheffield ... ... Dec. 2, 1871.
96 Chapman, M., Plashetts Colliery, Falstone, Northd.... Aug. 1, 1868.
97 Charlton, E., Evenwood Colliery, Bishop Auckland ... Sept. 5, 1868.
98 Charlton, F., C.E., Newcastle-on-Tyne ... ... Sept. 2, 1871.
99 Checkley, Thomas, M.E., Lichfield Street, Walsall ... Aug. 7, 1869.
100 Childe, Rowland, Wakefield, Yorkshire ... ... May 15, 1862.
101 Clark, C. F., Garswood, Newton-le-Willows ... ... Aug. 2, 1866.
102 Clark, G., Ravenhead Colliery, St. Helen's, Lancashire Dec. 7, 1867.
103 Clark, R. P., 9, St. Mary's Terrace, Newcastle ... Nov. 7, 1868.
104 Clark, W., M.E., The Grange, Teversall, nr. Mansfield April 7, 1866
105 Clark, William, Victoria Engine Works, Gateshead ... Dec. 7, 1867.
106 Clarke, T., Ince Hall Collieries, Wigan ... ... Mar. 2, 1872.
107 Clifford, W. ... ... Sept. 4, 1869.
108 Coates, C. N., Skelton Mines, by Guisborough ... May 3, 1866.
109 COCHRANE, W., Oakfield House, Coxlodge, Northumberland ... ... (VICE-PRESIDENT) 1859.
110 Cochrane, B., Alden Grange, Durham ... ... Dec. 6, 1866.
111 Cochrane, C., The Grange, Stourbridge ... ... June 3, 1857.
112 Cochrane, H., The Longlands, Middlesbro'-on-Tees ... Mar. 4, 1871.
113 Cockburn, G., 8, Summerhill Grove, Newcastle ... Dec. 6, 1866.
114 Cockburn, W., Upleatham Mines, Upleatham, Marske Oct. 1, 1857.
115 Coke, R. G., Tapton Grove, Chesterfield, Derbyshire May 5, 1859.
116 Cole, W. R., Bebside Colliery, Cowpen Lane, Northd. Oct. 1, 1857.
117 Collis, W. B., Heigh House, Stourbridge, Worcestershr. June 6, 1861.
118 Cook, J., jun., Washington Iron Works, Gateshead ... May 8, 1869.
119 Cook, R. F., Towlaw Iron Works, near Darlington ... 1860.
120 Cooke, John, 4, Mulberry Street, Darlington ... Nov. 1, 1860.
121 Cooksey, Joseph, West Bromwich, Staffordshire ... Aug. 3, 1865.
122 Cooper, P., Thornley Colliery Office, Ferryhill ... Dec. 3, 1857.
123 Cooper, R. E., C.E., York Place, Leeds ... ... Mar. 4, 1871.
124 Cooper, T., Park Gate, Rotherham, Yorkshire ... April 2, 1863.
125 Corbett, V. W., Londonderry Offices, Seaham Harbour Sept. 3, 1870.
126 Coulson, W., Shamrock House, Durham ... ... Oct. 1, 1852.
127 Cowen, J., jun., Blaydon Burn, Newcastle-on-Tyne Oct. 5, 1854.

ELECTED.

128 Cowlishaw, J., Thorncliffe, &c., Collieries, near Sheffield Mar. 7, 1867.
129 Coxon, Henry, Quay, Newcastle-on-Tyne ... ... Sept. 2, 1871.
130 Coxon, S. B., Usworth Colliery, Washington Station, Co. Durham ... ... June 5, 1856.
131 Craig, W. Y., Harecastle Colliery, Stoke-upon-Trent Nov. 3, 1866.
132 Crawford, T., Littletown Colliery, near Durham ... Aug. 21, 1852.
133 Crawford, T., Hetton Office, Fence Houses ... ... Sept. 3, 1864.
134 Crawford, T., jun., Littletown Colliery, near Durham Aug. 7, 1869.
135 Crawshay, E., Gateshead-on-Tyne ... ... Dec. 4, 1869.
136 Crawshay, G., Gateshead-on-Tyne ... ... Dec. 4, 1869.
137 Creighton, C. E., 10, Grey Street, Newcastle-on-Tyne May 6, 1871.
138 Crofton, J. G., Kenyon Collieries, Ruabon, Denbighshire Feb. 7, 1861.
139 Crone, S. C., Killingworth Colliery, Newcastle-upon-Tyne ... ... (*Member of Council*) 1853.
140 Crone, J. R., Stanhope, Darlington ... ... Feb. 1, 1868.
141 Cross, John, 78, Cross Street, Manchester ... ... June 5, 1869.
142 Croudace, Thomas, Lambton Lodge, New South Wales 1862.
143 Croudace, T. Dacre, Zeche Erin, Castrop, Westphalia Mar. 7, 1867.

144 Daglish, John, F.G.S., Tynemouth (Vice-President) Aug. 21, 1852.
145 Daglish, W. S., Solicitor, Newcastle ... ... July 2, 1872.
146 Dakers, W., Seaham Collieries, Sunderland ... ... April 7, 1866.
147 Dale, David, West Lodge, Darlington ... ... Feb. 5, 1870.
148 D'Andrimont, T., Liége, Belgium ... ... Sept. 3, 1870.
149 Daniel, W., 11, Blenheim Square, Leeds ... ... June 4, 1870.
150 Darlington, John, 2, Coleman Street Buildings, Moorgate Street, Great Swan Ally, London ... ... April 1, 1865.
151 Davidson, James, Newbattle Colliery, Dalkeith ... 1854.
152 Davidson, J., Blyth Place, St. Bees, nr. Whitehaven Feb. 1, 1868.
153 Davison, A., Seaton Delaval, Dudley, Northumberland Feb. 4, 1858.
154 Davy, Alfred, Park Iron Works, Sheffield ... ... Feb. 5, 1870.
155 Dawson, T. J., Cleugh Road, Masbro', Yorkshire ... April 6, 1867.
156 Day, W. H., Monk Bretton, Barnsley ... ... Mar. 6, 1869.
157 Dees, J., Whitehaven ... ... Nov. 1, 1855.
158 Dees, R. R., Solicitor, Newcastle-on-Tyne ... ... Oct. 7, 1871.
159 Dickinson, G. T., Wheelbirks, Northumberland ... July 2, 1872.
160 Dickinson, R., Coalowner, Shotley Bridge ... ... Mar. 4, 1871.
161 Dickinson, W. R., South Derwent Colliery, Annfield Plain, Gateshead ... ... Aug. 7, 1862.

		ELECTED.
162	Dixon, George, Lowther Street, Whitehaven... ...	Dec. 3, 1857.
163	Dobson, Thomas, Halton-lea-Gate, Haltwhistle ...	Mar. 7, 1868.
164	Dobson, W., Lambley Colliery, Haltwhistle	Sept. 4, 1869.
165	Dodd, B., Loughbrow, Hexham	May 3, 1866.
166	Dorning, Elias, 41, John Dalton Street, Manchester...	Aug. 3, 1865.
167	DOUGLAS, T., Peases' West Collieries, Darlington *(Member of Council)*	Aug. 21, 1852.
168	Douglas, C. P., Consett Iron Works, Gateshead ...	Mar. 6, 1869.
169	Douthwaite, T., Hebburn Colliery, Gateshead ...	June 5, 1869.
170	Dove, G., Portland Square, Carlisle	July 2, 1872.
171	Dunlop, Colin, jun., Quarter Iron Works, Hamilton...	Sept. 3, 1870.
172	Dunn, A. M., Architect, Newcastle-on-Tyne... ...	Mar. 6, 1869.
173	Dunn, D. G., Greenfield Collieries, Hamilton, N.B....	April 6, 1867.
174	Dunn, J., Drummond Colliery, Pictou, Nova Scotia...	May 8, 1869.
175	Dyson, George, Middlesborough	June 2, 1866.
176	Easton, J., Nest House, Gateshead	1853.
177	Eaton, J. R., 5, Saville Place, Newcastle-on-Tyne ...	Dec. 4, 1869.
178	ELLIOT, G., M.P., Houghton Hall, Fence Houses (PAST PRESIDENT, Member of Council.)	Aug. 21, 1852.
179	Elliott, W., Weardale Iron Works, Towlaw, Darlington	1854.
180	Embleton, T. W., The Cedars, Methley, Leeds ...	Sept. 6, 1855.
181	Embleton, T. W., jun., The Cedars, Methley, Leeds...	Sept. 2, 1865.
182	Eminson, J. B., Londonderry Offices, Seaham Harbour	Mar. 2, 1872.
183	Emslie, J. T., Harewood Villas, Stockton-on-Tees ...	Sept. 3, 1870.
184	Everard, I. B., M.E., 6, Millstone Lane, Leicester ...	Mar. 6, 1869.
185	Farmer, A., Westbrook, Darlington	Mar. 2, 1872.
186	Farrar, T., Barnsley	July 2, 1872.
187	Fearn, John Wilmot, Chesterfield	Mar. 6, 1869.
188	Fenwick, Barnabas, Team Colliery, Gateshead ...	Aug. 2, 1866.
189	Fenwick, George, Banker, Newcastle-on-Tyne ...	Sept. 2, 1871.
190	Fidler, E., Platt Lane Colliery, Wigan, Lancashire ...	Sept. 1, 1866.
191	Firth, S., M.A., 14, Springfield Mount, Leeds ...	1865.
192	Firth, William, Burley Wood, Leeds	Nov. 7, 1863.
193	Fisher, R. C., Ystalyfera, near Swansea	July 2, 1872.
194	Fletcher, G., Trimdon Colliery, Trimdon Grange ...	April 4, 1868.
195	Fletcher, H., Ladyshore Coll., Little Lever, Bolton, Lan.	Aug. 3, 1865.
196	Fletcher, I., M.P., Clifton Colliery, Workington ...	Nov. 7, 1863.
197	Fletcher, J., C.E., 69, Lowther Street, Whitehaven...	1857.

ELECTED.

198 Foord, J. B., Secretary, General Mining Association, 52, Old Broad Street, London ... ... Nov. 5, 1852.
199 Forrest, J., Pentrehobin Hall, Mold, Flintshire ... Mar. 5, 1870.
200 Forster, T. E., 7, Ellison Place, Newcastle-on-Tyne (Past President, Member of Council.) Aug. 21, 1852.
201 Forster, G. B., M.A., Backworth House, near Newcastle-upon-Tyne ... (Vice-President) Nov. 5, 1852.
202 Forster, George E., Washington, Gateshead ... ... Aug. 1, 1868.
203 Forster, J. R., Water Co.'s Office, Newcastle... ... July 2, 1872.
204 Forster, R., Trimdon Grange Colliery, Ferryhill ... Sept. 5, 1868.
205 Fothergill, J., King Street, Quay, Newcastle... ... Aug. 7, 1862.
206 Fowler, G., Basford Hall, near Nottingham ... ... July 4, 1861.
207 Fowler, W. C., Hucknall Torkard, Nottingham ... Aug. 6, 1870.
208 France, W., White Rose House, Marske-by-the-Sea April 6, 1867.
209 Frazer, B., Quay, Newcastle-upon-Tyne ... ... Oct. 4, 1866.
210 Frazer, W., Quay, Newcastle-upon-Tyne ... ... Oct. 4, 1866.
211 Fryar, M., C.E., Post Office, Rangoon, British Burmah Sept. 7, 1867.
212 Furness, H. D., Whickham, Gateshead-on-Tyne ... Dec. 2, 1871.
213 Gainsford, T. R., Belle Vue, near Sheffield ... ... Nov. 5, 1864.
214 Garforth, W. E., Lord's Field Colliery, Ashton-under-Lyne ... ... Aug. 2, 1866.
215 Gille, J., Ingènieur au Corps Royal des Mines, Mons. Sept. 2, 1871.
216 Gillett, F. C., 16, Tenant Street, Derby ... ... July 4, 1861.
217 Gilroy, G., Ince Hall Colliery, Wigan, Lancashire ... Aug. 7, 1856.
218 Gilroy, S. B., M.E., Moreton Hall and Preesgwyn Collieries, Chirk, North Wales ... ... Sept. 5, 1868.
219 Glover, B. B., M.E., Newton-le-Willows, Lancashire Aug. 2, 1866.
220 Goddard, D. H., Newcastle-on-Tyne ... ... July 2, 1872.
221 Goddard, E., Oak Hall, Ipswich ... ... July 2, 1872.
222 Goddard, W., Golden Hill Coll., Longton, No. Staff. Mar. 6, 1862.
223 Gooch, G. H., Lintz Colliery, Burnopfield, Gateshead Oct. 3, 1856.
224 Goodman, A., Walker Iron Works, Newcastle ... Sept. 5, 1868.
225 Gott, Wm. L., Shincliffe Collieries, Durham ... ... Sept. 3, 1864.
226 Graham, J., Dipton Colliery, near Burnopfield ... April 2, 1870.
227 Grant, J. H., Bora Chuck House, Seetarampore Collieries, Bengal ... ... Sept. 4, 1869.
228 Gray, Thomas, Underhill, Taibach ... ... June 5, 1869.
229 Greaves, J. O., Roundwood Coll., Horbury, Wakefield Aug. 7, 1862.
230 Green, J. T., Tredegar Ironworks, Monmouthshire ... Dec. 3, 1870.
231 Green, W., jun., Garesfield Col., Blaydon-on-Tyne ... Feb. 4, 1853.

ELECTED.

232 Greener, Thos., Benton Lodge, Darlington ... ... Aug. 3, 1865.
233 Greenwell, G. C., F.G.S., Poynton and Worth Collieries, Stockport ... ... Aug. 21, 1852.
234 Greenwell, G. C., jun., Poynton and Worth Collieries, Stockport ... ... Mar. 6, 1869.
235 Greig, D., Leeds ... ... Aug. 2, 1866.
236 Grey, C. G., Dilston, Northumberland ... ... May 4, 1872.
237 Griffith, N. R , 13, Grosvenor Road, Wrexham ... 1866.
238 Grimshaw, E. J., Cowley Hill, St. Helen's, Lancashire Sept. 5, 1868.
239 Guinotte, Lucien, Directeur des Charbonnages de Mariemont et de Bascoup, Mons ... ... Sept. 2, 1871.

240 Haggie, P., Gateshead ... ... 1854.
241 Hales, C., Modubeagh Ho., Ballylinan, Athy, Ireland 1865.
242 Hall, Edward, 24, Bigg Market, Newcastle ... ... Oct. 3, 1868.
243 Hall, F. W., 23, St. Thomas' Street, Newcastle ... Aug. 7, 1869.
244 Hall, H., Hamsteels Collieries, near Durham ... Aug. 2, 1866.
245 Hall, M., Brancepeth Colliery Offices, Willington, Co. Durham ... ... Sept. 5, 1868.
246 Hall, William F., Haswell Colliery, Fence Houses ... May 13, 1858.
247 Hann, Edmund, Lofthouse, Cleveland ... ... Sept. 5, 1868.
248 Hargreaves, William, Rothwell Haigh, Leeds ... Sept. 5, 1868.
249 Harkness, A., Birtley Iron Works, Fence Houses ... Dec. 5, 1868.
250 Harper, J. P., All Saints' Chambers, Derby ... ... Feb. 2, 1867.
251 Harper, Matthew, Whitehaven ... ... Oct. 1, 1863.
252 HARRISON, T. E., C.E., Central Station, Newcastle (*Member of Council*) May 6, 1853.
253 Harrison, R., Eastwood Collieries, Nottingham ... 1861.
254 Harrison, W. B., Norton Hall, Cannock, Staffordshire April 6, 1867.
255 Haswell, G. H., 11, So. Preston Terrace, No. Shields Mar. 2, 1872.
256 HAWTHORN, T., 74, Rye Hill, Newcastle (*Member of Council*) Dec. 6, 1866.
257 Hawthorn, W., C.E., 92, Pilgrim Street, Newcastle Mar. 4, 1853.
258 Head, J., Newport Rolling Mills, Middlesbro' ... Oct. 2, 1869.
259 Heckels, R., Wearmouth Colliery, Sunderland ... Nov. 5, 1852.
260 Hedley, Edward, Osmaston Street, Derby ... ... Dec. 2, 1858.
261 Hedley, T. F., Valuer, Sunderland ... ... Mar. 4, 1871.
262 HEDLEY, W. H., Consett Collieries, Medomsley, Burnopfield, Co. Durham ... (*Member of Council*) 1864.

		ELECTED.
263	Henderson, John, M.P., Leazes House, Durham ...	Mar. 5, 1870.
264	Heppell, T., Pelaw Main Collieries, Birtley, Fence Houses	Aug. 6, 1863.
265	Heppell, W., Brancepeth Coll., Willington, Co. Durham	Mar. 2, 1872.
266	Hepplewhite, T., Hetton Colliery, Fence Houses ...	Dec. 5, 1868.
267	Herdman, J., Park Crescent, Bridgend, Glamorganshire	Oct. 4, 1860.
268	Heslop, James, Esh Colliery, Durham	Feb. 6, 1864.
269	Hetherington, D., Coxlodge Colliery, Newcastle ...	1859.
270	Hewitt, G. C., Coal Pit Heath Colliery, near Bristol...	June 3, 1871.
271	Hewlett, A., Haigh Colliery, Wigan, Lancashire ...	Mar. 7, 1861.
272	Hick, G. W., 14, Blenheim Terrace, Leeds	May 4, 1872.
273	Higson, Jacob, 94, Cross Street, Manchester	1861.
274	Higson, P., jun., Hope View, Eccles, near Manchester	Aug. 3, 1865.
275	Hill, P., Littleburn Colliery, near Durham	July 2, 1872.
276	Hilton, J., Dunkirk Collieries, Dukinfield	Dec. 7, 1867.
277	Hilton, T. W., Wigan Coal & Iron Co., Limited, Wigan	Aug. 3, 1865.
278	Hodgkin, T., Banker, Newcastle-on-Tyne	Sept. 2, 1871.
279	HODGSON, R., Whitburn, Sunderland (*Mem. of Council*)	Feb. 7, 1856.
280	Homer, Charles James, Chatterley Hall, Tunstall ...	Aug. 3, 1865.
281	Hood, A., 6, Bute Crescent, Cardiff	April 18, 1861.
282	Hopper, John J., Britannia Iron Works, Fence Houses	Sept. 2, 1865.
283	Horsfall, J. J., Bradley Green Colliery, near Congleton	Mar. 2, 1865.
284	Horsley, W., Whitehill Point, Percy Main	Mar. 5, 1857.
285	Hoskold, H. D., Cinderford, Newnham, Gloucestershire	April 1, 1871.
286	Howard, W. F., 13, Cavendish Street, Chesterfield ...	Aug. 1, 1861.
287	Hoyt, J., Acadia Coal Mines, Pictou, Nova Scotia ...	May 8, 1869.
288	Hudson, James, Albion Mines, Pictou, Nova Scotia ..	1862.
289	Humble, John, West Pelton, Chester-le-Street ...	Mar. 4, 1871.
290	Humble, Jos., jun., Garesfield, Blaydon-on-Tyne ...	June 2, 1866.
291	Humble, W. J., Forth Banks West Factory, Newcastle	Sept. 1, 1866.
292	Hunt, A. H., Quayside, Newcastle-upon-Tyne ...	Dec. 6, 1862.
293	Hunter, Wm., Moor Lodge, Newcastle-upon-Tyne ...	Aug. 21, 1852.
294	Hunter, W., Morriston, Swansea, Glamorganshire ...	Oct. 3, 1861.
295	Hunter, W. S., Moor Lodge, Newcastle-upon-Tyne ...	Feb. 1, 1868.
296	Hunting, Charles, Fence Houses	Dec. 6, 1866.
297	Huntsman, Benjamin, West Retford Hall, Retford ...	June 1, 1867.
298	Hurd, F., Albion Foundry, Wakefield...	Dec. 4, 1869.
299	HURST, T. G., F.G.S., Riding Mill, Northumberland (*Member of Council*)	Aug. 21, 1852.
300	Hutchings, W. M., 5, Bouverie St., Fleet St., London	Sept. 5, 1868.

ELECTED.

301 Hutchinson, G., Howden Colliery, Darlington ... July 2, 1872.

302 Jackson, C. G., Ladies' Lane Colliery, Hindley, Wigan June 4, 1870.
303 Jameson, John, Printing Court Chambers, Newcastle Nov. 6, 1869.
304 Jarratt, J., Broomside Colliery Office, Durham ... Nov. 2, 1867.
305 Jeffcock, T. W., 18, Bank Street, Sheffield ... ... Sept. 4, 1869.
306 Jenkins, W., M.E., Ocean S.C. Collieries, Ystrad, near Pontypridd, South Wales ... ... Dec. 6, 1862.
307 Johnasson, J., 5, Gloucester Sq., Hyde Park, London July 2, 1872.
308 Johnson, Henry, Dudley, Worcestershire ... ... Aug. 7, 1869.
309 Johnson, John, M. Inst. C.E., F.G.S., Osborne Terrace, Jesmond Road, Newcastle ... ... Aug. 21, 1852.
310 Johnson, R. S., Sherburn Hall, Durham ... ... Aug. 21, 1852.
311 Johnson, T., Withington Hill Colliery, Aspull, nr. Wigan Aug. 7, 1869.
312 Johnson, W. J., W.B. Lead Works, Allendale ... April 6, 1872.
313 Johnston, T., Widdrington Colliery, Acklington ... April 6, 1872.
314 Joicey, E., Coal Owner, Newcastle-on-Tyne ... .. April 6, 1872.
315 Joicey, J. G., Forth Banks West Factory, Newcastle April 10, 1869.
316 Joicey, John, Newton Hall, Stocksfield-on-Tyne ... Sept. 3, 1852.
317 Joicey, W. J., Tanfield Lea Colliery, Burnopfield ... Mar. 6, 1869.
318 Jones, E., Granville Lodge, Wellington, Salop ... Oct. 5, 1854.
319 Jones, John, F.G.S., Secretary, North of England Iron Trade, Middlesbro'-on-Tees ... ... Sept. 7, 1867.
320 Joseph, T., Ty Draw, near Pontypridd, South Wales April 6, 1872.

321 Kendall, W., Blyth and Tyne Railway, Percy Main ... Sept. 1, 1866.
322 Kennedy, Myles, M.E., Hill Foot, Ulverstone ... June 6, 1868.
323 Kirkwood, William, Larkhall Colliery, Hamilton ... Aug. 7, 1869.
324 Knowles, A., High Bank, Pendlebury, Manchester ... Dec. 5, 1856.
325 Knowles, A., jun., The Poplars, Hope Eccles, near Manchester ... ... Dec. 3, 1863.
326 Knowles, John, Pendlebury Colliery, Manchester ... Dec. 5, 1856.
327 Knowles, Kaye, Little Lever Colliery, near Bolton ... Aug. 3, 1865.
328 Knowles, R. M., Turton, near Bolton ... ... Aug. 3, 1865.
329 Knowles, Thomas, Ince Hall, Wigan ... ... Aug. 1, 1861.

330 Lamb, R., Cleator Moor Colliery, near Whitehaven ... Sept. 2, 1865.
331 Lamb, R. O., Axwell Park, Gateshead ... ... Aug. 2, 1866.
332 Lambert, M. W., 44, Quay, Newcastle ... ... July 2, 1872.

ELECTED.

333 Lancaster, John, Bilton Grange, Rugby ... ... July 4, 1861.
334 Lancaster, J., jun., Bilton Grange, Rugby ... ... Mar. 2, 1865.
335 Lancaster, Joshua, Mostyn Collieries, near Holywell Aug. 3, 1865.
336 Lancaster, S., Prescot Colliery, Prescot ... ... Aug. 3, 1865.
337 Landale, A., Lochgelly Iron Works, Fifeshire, N.B. Dec. 2, 1858.
338 Lange, C., Broad Chare, Newcastle-on-Tyne ... ... Mar. 5, 1870.
339 Laverick, J., West Rainton, Fence Houses ... ... July 2, 1872.
340 Lawrence, Henry, Grange Iron Works, Durham ... Aug. 1, 1868.
341 Laws, H., Grainger Street West, Newcastle-on-Tyne (*Member of Council*) Feb. 6, 1869.
342 Laws, John, Blyth, Northumberland ... ... 1854.
343 Lawson, Rev. E., Longhirst Hall, Morpeth ... ... Dec. 3, 1870.
344 Lawson, J. P., Victoria Mines, Sydney, Cape Breton Dec. 3, 1870.
345 Laycock, Joseph, Low Gosforth, Northumberland ... Sept. 4, 1869.
346 Leather, J. T., Middleton Hall, Belford, Northumbld. Aug. 6, 1870.
347 Lee, George, Eston Mines, Middlesbro' ... ... June 4, 1870.
348 Legrand, A., Mons, Belgium ... ... June 5, 1869.
349 Leslie, Andrew, Hebburn, Gateshead-on-Tyne ... Sept. 7, 1867.
350 Letoret, Jules, Flenu, near Mons, Belgium ... ... Sept. 4, 1869.
351 Lever, Ellis, West Gorton Works, Manchester ... 1861.
352 Lewis, G., Coleorton Colliery, Ashby-de-la-Zouch ... Aug. 6, 1863.
353 Lewis, Henry, Annesley Colliery, near Mansfield ... Aug. 2, 1866.
354 Lewis, Lewis Thomas, Cadoxton Lodge, Neath ... Feb. 1, 1868.
355 Lewis, William Thomas, Mardy, Aberdare ... ... 1864.
356 Liddell, G. H., Murton Colliery, Fence Houses ... Sept. 4, 1869.
357 Liddell, J. R., Nedderton, Northumberland ... ... Aug. 21, 1852.
358 Liddell, M., Prudhoe Hall, Prudhoe-on-Tyne ... Oct. 1, 1852.
359 Lindop, James, Bloxwich, Walsall, Staffordshire ... Aug. 1, 1861.
360 Linsley, R., Seghill Colliery, Northumberland ... July 2, 1872.
361 Linsley, S.W., Silksworth New Winning, nr. Sunderland Sept. 4, 1869.
362 Lishman, John, Western Hill, Durham ... ... June 2, 1866.
363 Lishman, T., jun., Black Boy Coll., nr. Bishop Auckland Nov. 5, 1870.
364 Lishman, Wm., Etherley Colliery, Darlington ... 1857.
365 Lishman, Wm., Bunker Hill, Fence Houses ... ... Mar. 7, 1861.
366 Lister, Clement, Newcastle-on-Tyne ... ... June 4, 1870.
367 Livesey, C., Bredbury Colliery, Bredbury, Stockport Aug. 3, 1865.
368 Livesey, T., Chamber Hall, Hollinwood, Manchester ... Aug. 1, 1861.
369 Llewellin, D., Glanwern Offices, Pontypool, Monmouthshire ... ... Aug. 4, 1864.

		ELECTED.
370	Llewelyn, L., Aberaman, Aberdare, South Wales ...	May 4, 1872.
371	Logan, William, Littletown, Durham	Sept. 7, 1867.
372	Longridge, J., 3, Poet's Corner, Westminster, London	Aug. 21, 1852.
373	Love, Joseph, Brancepeth Colliery, Durham	Sept. 5, 1856.
374	Low, W., Vron Colliery, Wrexham, Denbighshire ...	Sept. 6, 1855.
375	Lupton, A., F.G.S., 4, Blenheim Terrace, Leeds ...	Nov. 6, 1869.
376	Mackenzie, J., 4, West Regent Street, Glasgow ...	Mar. 5, 1870.
377	Maddison, W. P., Thornhill Collieries, near Dewsbury	Oct. 6, 1859.
378	Mammatt, John E., C.E., Wortley Grange, Leeds ...	1864.
379	MARLEY, JOHN, Mining Offices, Darlington (VICE-PRESIDENT)	Aug. 21, 1852.
380	Marshall, F. C., Messrs. Hawthorn and Co., Newcastle	Aug. 2, 1866.
381	Marshall, J., Smithfold Coll., Little Hulton, nr. Bolton	1864.
382	Marston, W. B., Leeswood Vale Oil Works, Mold ...	Oct. 3, 1868.
383	Mart, B., St. Peter's Chambers, Oak Hill, Stoke-on-Trent	Sept. 4, 1869.
384	Marten, E. B., C.E., Pedmore, near Stourbridge ...	July 2, 1872.
385	Matthews, R. F., So. Hetton Colliery, Fence Houses	Mar. 5, 1857.
386	Maughan, J. A., Wallsend Colliery, Newcastle ...	Nov. 7, 1863.
387	May, George, North Hetton Colliery, Fence Houses	Mar. 6, 1862.
388	McCreath, J., 138, West George Street, Glasgow ...	Mar. 5, 1870.
389	McCulloch, H. J., Jesmond Villa, Park Road, Holloway, London, N.	Oct. 1, 1863.
390	McGhie, T., Cannock, Staffordshire	Oct. 1, 1857.
391	McIntyre, James, Shipbuilder, Jarrow-on-Tyne ...	Sept. 2, 1871.
392	McMurtrie, J., Radstock Colliery, Bath	Nov. 7, 1863.
393	McMurtrie, W. G., Camerton Collieries, near Bath ...	Sept. 4, 1869.
394	Meik, Thomas, C.E., Sunderland	June 4, 1870.
395	Miller, Robert, Strafford Collieries, near Barnsley ...	Mar. 2, 1865.
396	Mills, John, Forth Street, Newcastle	July 2, 1872.
397	Mitcalfe, W. B., 23 and 24, Coal Exchange, London	Nov. 6, 1869.
398	Mitchinson, R., jun., Kibblesworth Col., Gateshead ...	Feb. 4, 1865.
399	Moffatt, T., New Mains, by Motherwell, N.B. ...	Sept. 4, 1869.
400	Monkhouse, Jos., Gill Head Colliery, Flimby, Maryport	June 4, 1863.
401	Moody, John, Alipore Road, Calcutta	Feb. 3, 1872.
402	Moor, T., North Seaton Colliery, Morpeth	Oct. 3, 1868.
403	Moore, T. H., Smeaton Park, Inveresk, Edinburgh ...	Feb. 2, 1867.
404	MORISON, D. P., 21, Collingwood Street, Newcastle (*Member of Council*)	1861.

ELECTED.

405 Morris, W., Waldridge Colliery, Chester-le-Street, Fence Houses ... ... 1858.
406 Morrison, James, 34, Grey Street, Newcastle-upon-Tyne Aug. 5, 1853.
407 Morton, H. T., Lambton, Fence Houses ... ... Aug. 21, 1852.
408 Muckle, John, Monk Bretton, Barnsley ... ... Mar. 7, 1861.
409 Mulcaster, Joshua, Crosby Colliery, Maryport ... June 4, 1863.
410 Mulcaster, W., jun., M.E., Maryport ... ... Dec. 3, 1870.
411 Mulvany, W. T., 1335, Carls Thor, Dusseldorf-on-the-Rhine ... ... Dec. 3, 1857.
412 Murray, T. H., Chester-le-Street, Fence Houses ... Apr. 18, 1861.

413 Nanson, J., 4, Queen Street, Newcastle-on-Tyne ... Dec. 4, 1869.
414 Napier, C., 1, Rumford Place, Liverpool ... ... Aug. 1, 1861.
415 Nasse, Rud., Louisenthal, Saarbruck, Prussia ... Sept. 4, 1869.
416 Naylor, J. T., 10, West Clayton Street, Newcastle ... Dec. 6, 1866.
417 NELSON, J., C.E., King's House Engine Works, Sunderland ... ... (*Member of Council*) Oct. 4, 1866.
418 Nevin, John, Mirfield, Yorkshire ... ... May 2, 1868.
419 NEWALL, R. S., Ferndene, Gateshead (VICE-PRESIDENT) May 2, 1863.
420 Newby, J. E., Usworth Colliery, Gateshead ... ... Oct. 2, 1869.
421 Nicholson, E., jun., Beamish Colliery, by Chester-le-Street, Fence Houses ... ... Aug. 7, 1869.
422 Nicholson, Marshall, Middleton Hall, Leeds ... ... Nov. 7, 1863.
423 Nicholson, R., Blaydon-on-Tyne ... ... July 2, 1872.
424 Nicholson, T., Park Lane Engine Works, Gateshead ... Dec. 4, 1869.
425 Nicholson, W., Seghill Colliery, Newcastle ... ... Oct. 1, 1863.
426 Noble, Captain, Jesmond, Newcastle-upon-Tyne ... Feb. 3, 1866.
427 Noble, R. B., Pensher, Fence Houses ... ... Oct. 2, 1869.
428 North, F. W., Rowley Hall Col., Dudley, Staffordshire Oct. 6, 1864.

429 Ogden, John M., Solicitor, Sunderland ... ... Mar. 5, 1857.
430 Oliver, G., Brotton Ironstone Mines, Saltburn-by-the-Sea 1864.
431 Oliver, John, Hawkesbury Colliery, Bedworth ... April 1, 1865.
432 Oliver, W., Stanhope Burn Offices, Stanhope, Darlington 1862.
433 Owen, R., 40, Dean Street, Newcastle ... ... July 2, 1872.

434 Pacey, T., Bishop Auckland ... ... Apr. 10, 1869.
435 Palmer, A. M., Wardley Colliery, Durham ... ... July 2, 1872

		ELECTED.
436	Palmer, C. M., Quay, Newcastle-upon-Tyne	Nov. 5, 1852.
437	Palmer, John, Jarrow-on-Tyne	April 1, 1871.
438	Papik, Johanne, Teplitz, Bohemia	Feb. 5, 1870.
439	Parrington, M. W., So. Skelton Mines, Marske-by-the-Sea	Dec. 1, 1864.
440	Parton, T., F.G.S., New Road, Willenhall, near Wolverhampton	Oct. 2, 1869.
441	Pattinson, John, Analytical Chemist, Newcastle-on-Tyne	May 2, 1868.
442	Patton, John, Westoe, South Shields	April 6, 1872.
443	Peace, M. W., Wigan, Lancashire	July 2, 1872.
444	Peacock, David, Horsley, Tipton	Aug. 7, 1869.
445	Pearce, F. H., Bowling Iron Works, Bradford ...	Oct. 1, 1857.
446	Pearson, J. E., Golborne Park, near Newton-le-Willows	Feb. 3, 1872.
447	Pease, J. W., M.P., Woodlands, Darlington	Mar. 5, 1857.
448	Peel, John, Springwell Colliery, Gateshead	Nov. 1, 1860.
449	Peile, William, 6, College Street, Whitehaven ...	Oct. 1, 1863.
450	Perrot, S. W., Hibernia and Shamrock Collieries, Gelsenkirchen, Dusseldorf	June 2, 1866.
451	Philipson, H., 8, Queen Street, Newcastle-on-Tyne ...	Oct. 7, 1871.
452	Pickersgill, T., Waterloo Main Colliery, near Leeds ...	June 5, 1869.
453	Piggford, J., Houghall Colliery, near Durham ...	Aug. 2, 1866.
454	Pilkington, Wm., jun., St. Helen's, Lancashire ...	Sept. 6, 1855.
455	POTTER, W. A., Cramlington House, Northumberland (*Member of Council*)	1853.
456	Potter, Addison, Heaton Hall, Newcastle-on-Tyne ...	Mar. 6, 1869.
457	Priestman, Jon., Coal Owner, Newcastle-on-Tyne ...	Sept. 2, 1871.
458	Prosser, Thomas, Architect, Newcastle-on-Tyne ...	Mar. 6, 1869.
459	RAMSAY, J. A., Washington Colliery, near Durham (*Member of Council*)	Mar. 6, 1869.
460	Ramsay, J. T., Walbottle Hall, near Blaydon-on-Tyne	Aug. 3, 1853.
461	Ramsay, T. D., So. Durham Colliery, *via* Darlington	Mar. 1, 1866.
462	Redmayne, J. M., Chemical Manufacturer, Gateshead	July 2, 1872.
463	Redmayne, R. R., Chemical Manufacturer, Gateshead	Sept. 2, 1871.
464	Reed, Robert, Felling Colliery, Gateshead	Dec. 3, 1863.
465	Rees, Daniel, Lletty Shenkin Colliery, Aberdare ...	1862.
466	Reid, Andrew, Newcastle-on-Tyne	April 2, 1870.
467	Richardson, E., 2, Queen Street, Newcastle-on-Tyne	Feb. 5, 1870.
468	Richardson, H., Backworth Colliery, Newcastle ...	Mar. 2, 1865.

		ELECTED.
469	Richardson, J. W., Iron Shipbuilder, Newcastle-on-Tyne	Sept. 3, 1870.
470	Ridley, G., care of Brumell & Russel, Toronto, Canada	Feb. 4, 1865.
471	Ridley, J. H., R. and W. Hawthorn's, Newcastle ...	April 6, 1872.
472	Ritson, U. A., 6, Queen Street, Newcastle-on-Tyne ...	Oct. 7, 1871.
473	Robertson, W., M.E., 123, St. Vincent Street, Glasgow	Mar. 5, 1870.
474	Robinson, G. C., Shotton Colliery, Castle Eden ...	Nov. 5, 1870.
475	Robinson, H., C.E., 7, Westminster Chambers, London	Sept. 3, 1870.
476	Robinson, R., jun., Albion Cottage, Bishop Auckland	Feb. 1, 1868.
477	Robinson, R. H., Staveley Works, near Chesterfield	Sept. 5, 1868.
478	Robson, E., Newlands Villa, Middlesbro'-on-Tees ...	April 2, 1870.
479	Robson, J. B., Paradise, Newcastle-upon-Tyne ...	May 8, 1869.
480	Robson, J. S., Butterknowle Colliery, *via* Staindrop, Darlington	1853.
481	Robson, J. T., Towneley Colliery, Blaydon-on-Tyne	Sept. 4, 1869.
482	Robson, M., Coppa Colliery, near Mold, Flintshire ...	May 4, 1872.
483	Robson, Thomas, Lumley Colliery, Fence Houses ...	Oct. 4, 1860.
484	Robson, W. C., Colliery Office, Whitehaven	Sept. 4, 1869.
485	Rogerson, J., Weardale Iron and Coal Co., Newcastle	Mar. 6, 1869.
486	Ronaldson, J., Australia	Aug. 2, 1866.
487	Roscamp, J., Acomb Colliery, Hexham	Feb. 2, 1867.
488	Rose, Thomas, Merridale Grove, Wolverhampton ...	1862.
489	Ross, A., Shipcote Colliery, Gateshead	Oct. 1, 1857.
490	Ross, J. A. G., 31, Havelock Street, Newcastle ...	July 2, 1872.
491	Rosser, Wm., Mineral Surveyor, Llanelly, Carmarthenshire	1856.
492	Rothwell, R. P., Wilkes Barre, Pennsylvania, U.S.	Mar. 5, 1870.
493	Routledge, T., Lorway Coal Co. Limited, Sydney, Cape Breton	Dec. 3, 1870.
494	Routledge, Wm., Sydney, Cape Breton	Aug. 6, 1857.
495	Rusby, W. J., Glass House Fields Engine Works, Radcliffe, London, E.	Aug. 1, 1868.
496	Rutherford, J., Halifax, Nova Scotia	1866.
497	Sanderson, R. B., 33, Westgate Street, Newcastle (*Member of Council*)	1852.
498	Sanderson, T., Seaton Delaval, Dudley, Northumberd.	Aug. 7, 1862.
499	Scarth, W. T., Raby Castle, Darlington	April 4, 1868.
500	Scott, Andrew, Broomhill Colliery, Acklington ...	Dec. 7, 1867.
501	Scoular, G., Parkside, Frizington, Cumberland ...	July 2, 1872.

		ELECTED.
502	Seddon, J. F., Eccleshill Colliery, Darwen	June 1, 1867.
503	Seddon, W., Lower Moor Collieries, Oldham, Lancashire	Oct. 5, 1865.
504	Shallis, F. W., Bulman Village, Newcastle	April 6, 1872.
505	Shaw, W., jun., Wolsingham, *via* Darlington ...	June 3, 1871.
506	Shiel, John, Usworth Colliery, County Durham ...	May 6, 1871.
507	Shield, H., Lamb's Cottage, Gilesgate Moor, Durham	Mar. 6, 1862.
508	Shortrede, T., Park House, Winstanley, Wigan ...	April 3, 1856.
509	SIMPSON, J. B., Hedgefield House, Blaydon-on-Tyne (*Member of Council*)	Oct. 4, 1860.
510	Simpson, J., Rhos Llantwit Colliery, Caerphilly, near Cardiff	Dec. 6, 1866.
511	Simpson, L., South Garesfield Colliery, Burnopfield ...	1855.
512	Simpson, R., Ryton Moor House, Blaydon-on-Tyne	Aug. 21, 1852.
513	Slinn, T., Radcliffe House, Acklington	July 2, 1872.
514	Small, G., Kilburne Colliery, near Derby	June 4, 1870.
515	Smith, C. J., Darlington	July 2, 1872.
516	Smith, E. J., 14, Whitehall Place, Westminster, London	Oct. 7, 1858.
517	Smith, F., Bridgewater Offices, Manchester	Aug. 5, 1853.
518	Smith, T. E., M.P., Gosforth House, Dudley, Northd.	Feb. 5, 1870.
519	Smith, T. M., 1, Chapel Place, Duke Street, Westminster, London	Sept. 2, 1871.
520	Smith, Thomas Taylor, Urpeth Hall, Chester-le-Street	Aug. 2, 1866.
521	Sneddon, J., 149, West George Street, Glasgow ...	July 2, 1872.
522	Snowdon, T., jun., Weardale Iron Works, Towlaw, *via* Darlington	Sept. 4, 1869.
523	Sopwith, A., 103, Victoria Street, Westminster, London	Aug. 1, 1868.
524	Sopwith, T., F.G.S., etc., 103, Victoria Street, Westminster, London, S.W.	May 6, 1853.
525	Southern, R., Blaen Rhondda Colliery, Treherbert, by Pontypridd, South Wales	Aug. 3, 1865.
526	Spark, H. K., Darlington	1856.
527	Spence, J., Printing Court Buildings, Newcastle ..	July 2, 1872.
528	Spencer, John, Westgate Street, Newcastle	Sept. 4, 1869.
529	Spencer, M., Newburn, near Newcastle-on-Tyne ...	Sept. 4, 1869.
530	Spencer, T., Ryton, Newcastle-upon-Tyne	Dec. 6, 1866.
531	Spencer, W., 2, East Cross Street, Sunderland ...	Aug. 21, 1852.
532	Spooner, P., Haswell Colliery, Fence Houses ...	Dec. 4, 1869.
533	STEAVENSON, A. L., Holywell, Durham (VICE-PRESIDENT)	Dec. 6, 1855.

		ELECTED.
534	Steavenson, D. F., B.A., LL.B, Barrister-at-Law, Cross House, Westgate Street, Newcastle-on-Tyne ...	April 1, 1871.
535	Steele, Charles R., Ellenborough Colliery, Maryport	Mar. 3, 1864.
536	Stenson, W. T., Whitwick Coll., Coalville, nr. Leicester	Aug. 5, 1853.
537	Stephenson, G. R., 24, Great George Street, Westminster, London, S.W.	Oct. 4, 1860.
538	Stephenson, J., Seaton Delaval Coll., Dudley, Northum.	Sept. 5, 1868.
539	Stephenson, W. H., Summerhill Grove, Newcastle	Mar. 7, 1867.
540	Stevenson, Archibald, South Shields	Sept. 2, 1871.
541	Stobart, H. S., Witton-le-Wear, Darlington	Feb. 2, 1854.
542	Stobart, W., Cocken Hall, Fence Houses	July 2, 1872.
543	Stott, James, Chatham Hall, Manchester	1855.
544	Straker, John, West House, Tynemouth	May 2, 1867.
545	Swallow, John, Harton Colliery, South Shields ...	Aug. 6, 1863.
546	Swallow, R. T., Pontop Coll., Burnopfield, Co. Durham	1862.
547	Swan, H. F., Shipbuilder, Newcastle-on-Tyne ...	Sept. 2, 1871.
548	Swan, J. G., Upsall Hall, near Middlesbro'	Sept. 2, 1871.
549	Taylor, H., 27, Quay, Newcastle-upon-Tyne	Sept. 5, 1856.
550	Taylor, J., Earsdon, Newcastle-upon-Tyne	Aug. 21, 1852.
551	Taylor, T., Chipchase Castle, Northumberland ...	July 2, 1872.
552	Taylor, W. N., Ryhope Colliery, Sunderland ...	Oct. 1, 1863.
553	Telford, W., Cramlington, Northumberland	May 6, 1853.
554	Thomas, A., Bilson House, near Newnham, Glos. ...	Mar. 2, 1872.
555	Thompson, Astley, Kedwelly, Carmarthenshire ...	1864.
556	Thompson, James, Bishop Auckland	June 2, 1866.
557	Thompson, John, Marley Hill Colliery, Gateshead ...	Oct. 4, 1860.
558	Thompson, John, Field House, Hoole, Chester ...	Sept. 2, 1865.
559	Thompson, J., Norley Colliery, Wigan, Lancashire ...	April 6, 1867.
560	Thompson, R., jun., North Brancepeth Coll., nr. Durham	Sept. 7, 1867.
561	Thompson, T. C., Milton Hall, Carlisle	May 4, 1854
562	Thorpe, R. S., 17, Picton Place, Newcastle	Sept. 5, 1868.
563	Tinn, J., C.E., Ashton Iron Rolling Mills, Bower Ashton, Bristol	Sept. 7, 1867
564	Toller, J. E., Royal Engineers, Archcliff Fort, Dover	July 2, 1872.
565	Tone, J. F., C.E., Pilgrim Street, Newcastle-on-Tyne	Feb. 7, 1856.
566	Truran, M., Dowlais Iron Works, Merthyr Tydvil ...	Dec. 1, 1859.
567	Turner, W. B., C. and M.E., Ulverstone	Dec. 7, 1867.
568	Tylden-Wright, C., Shireoaks Coll., Worksop, Notts.	1862.

ELECTED.

569 Ure, J. F., Engineer, Tyne Commissioners, Newcastle May 8, 1869.

570 Vaughan, Thomas, Middlesbro'-on-Tees ... ... 1857.

571 Wadham, E., C. and M.E., Millwood, Dalton-in-Furness Dec. 7, 1867.
572 Wake, H. H., River Wear Commissioners, Sunderland Feb. 3, 1872.
573 Walker, G. W., Swannington, near Ashby-de-la-Zouch Sept. 7, 1867.
574 Walker, J. S., 15, Wallgate, Wigan, Lancashire ... Dec. 4, 1869.
575 Walker, W., Crags Hall Mines, Brotton, near Saltburn-by-the-Sea ... ... Mar. 5, 1870.
576 Waller, W., Palmer & Co., Limited, Jarrow-on-Tyne 1866.
577 Walton, W., Upleatham Mines, Redcar ... ... Feb. 1, 1867.
578 Ward, H., Priestfield Iron Works, Oaklands, Wolverhampton ... ... Mar. 6, 1862.
579 Wardell, S. C., Doe Hill House, Alfreton ... ... April 1, 1865.
580 Warrington, J., Worsborough Hall, near Barnsley ... Oct. 6, 1859.
581 Watkin, Wm. J. L., Pemberton Colliery, Wigan ... Aug. 7, 1862.
582 Watson, H., High Bridge, Newcastle-upon-Tyne ... Mar. 7, 1868.
583 Watson, M., Ludworth Colliery, Durham ... ... Mar. 7, 1868.
584 Webster, R. C., Ruabon Coll., Ruabon, Denbighshire Sept. 6, 1855.
585 Weeks, J. G., Staincross, near Barnsley ... ... Feb. 4, 1865.
586 Westmacott, P. G. B., Elswick Iron Works, Newcastle June 2, 1866.
587 Weymouth, J. F., King's House Engine Works, Sunderland ... ... July 2, 1872.
588 Whaley, Thomas, Orrell Mount, Wigan ... ... Aug. 2, 1866.
589 White, H., Ouston Colliery, Fence Houses ... ... 1866.
590 White, J. T., Altofts, near Normanton ... ... Mar. 1 1866.
591 Whitelaw, A., 168, West George Street, Glasgow ... Mar. 5, 1870.
592 Whitelaw, John, Fordel Colliery, Inverkeithing, N.B. Feb. 5, 1870.
593 Whitelaw, T., Shields and Dalzell Collieries, Motherwell April 6, 1872.
594 Whitwell, T., Thornaby Iron Works, Stockton-on-Tees Sept. 5, 1868.
595 Widdas, C., No. Bitchburn Coll., Howden, Darlington Dec. 5, 1868.
596 Wilkinson, G. W., Pensher Colliery, Fence Houses May 4, 1872.
597 Williams, E. (Bolckow, Vaughan, & Co.), Middlesbro' Sept. 2, 1865.
598 Williamson, John, Chemical Manufacturer, So. Shields Sept. 2, 1871.
599 WILLIS, JAMES, 13, Old Elvet, Durham (*Member of Council*) Mar. 5, 1857.
600 Willis, E., Clarence House, Willington, near Durham Sept. 5, 1868.
601 Wilmer, F. B., Duffryn Collieries, Aberdare... ... June 6, 1856.

ELECTED.

602 Wilson, J., 69, Great Clyde Street, Glasgow... ... July 2, 1872.
603 Wilson, J. B., Wingfield Iron Works & Coll., Alfreton Nov. 5, 1852.
604 Wilson, J. S., Bulman Village, Newcastle-on-Tyne Dec. 2, 1858.
605 Wilson, R., Flimby Colliery, Maryport ... ... April 3, 1856.
606 Wilson, T. H., Exchange Buildings, Quay, Newcastle Mar. 6, 1869.
607 Winship, J. B., Newcastle, Australia ... ... Dec. 4, 1869.
608 Winter, T. B., Grey Street, Newcastle-on-Tyne ... Oct. 7, 1871.
609 Wood, Lindsay, Hetton Hall, Fence Houses (*Member of Council*) Oct. 1, 1857.
610 Wood, C. L., Howlish Hall, Bishop Auckland ... 1853.
611 Wood, J., Flockton Collieries, Wakefield ... ... April 2, 1863.
612 Wood, Thomas, Westerton, Bishop Auckland ... Sept. 3, 1870.
613 Wood, W. H., West Hetton, Ferryhill ... ... 1856.
614 Wood, W. O., East Hetton Colliery, Ferryhill ... Nov. 7, 1863.
615 Woodgate, A., Chemical Manure Manr., Newcastle Feb. 3, 1872.
616 Woodhouse, J. T., Midland Road, Derby ... ... Dec. 13, 1852.
617 Wright, G. H., Babbington Collieries, Cinder Hill, Nottingham ... ... July 2, 1872.

618 Young, J., 3, St. Paul's Terrace, Newcastle ... ... July 2, 1872.

Students.

1 Atkinson, J. B., Chilton Moor, Fence Houses ... Mar. 5, 1870.
2 Atkinson, W. N., South Hetton Colliery, Fence Houses June 6, 1868.

3 Bell, C. E., 31, Old Elvet, Durham ... ... Dec. 3, 1870.
4 Boyd, R. F., Towneley Colliery, Blaydon-on-Tyne ... Nov. 6, 1869.
5 Bragge, G. S., Nunnery Colliery Offices, Sheffield ... July 2, 1872.
6 Brown, M. W., Portland Villa, Benton, Newcastle ... Oct. 7, 1871.

7 Chambers, W. Henry, 34, Nottingham Road, Alfreton Dec. 2, 1871.
8 Clark, H. P., 13, Cavendish Street, Chesterfield ... Mar. 4, 1871.
9 Clarke, N., jun., South Tanfield, Chester-le-Street ... June 6, 1868.
10 Cockburn, W. C., 8, Summerhill Grove, Newcastle ... July 2, 1872.
11 Coulson, F., Shamrock House, Durham ... ... Aug. 1, 1868.
12 Crone, E. W., Killingworth Hall, near Newcastle ... Mar. 5, 1870.

13 Dickinson, J. L., Belle Vue House, Shotley Bridge ... Aug. 6, 1870.

		ELECTED.
14	Dyson, O., 51, Maple Street, Newcastle	Mar. 2, 1872.
15	Fletcher, J., Kelton House, Dumfries	July 2, 1872.
16	Fletcher, W., Cowpen Colliery, Blyth	Feb. 4, 1871.
17	Forster, J. T., Washington, Gateshead	Aug. 1, 1868.
18	Fujimato, B., 2, Bedford Place, Newcastle	July 2, 1872.
19	Gerrard, J., Ince Hall Coal and Cannel Co., near Wigan	Mar. 5, 1870.
20	Gilmour, D., Hebburn Colliery, Wallsend	Feb. 3, 1872.
21	Grace, E. N., Lumley Colliery, Fence Houses ...	Feb. 1, 1868.
22	Greener, T. Y., Peases' West Collieries, Darlington ...	July 2, 1872.
23	Ground, H., Moor House, near Durham	July 2, 1872.
24	Hague, E., Hebburn Colliery, Wallsend	Mar. 2, 1872.
25	Hargreaves, H., Nunnery Colliery Offices, Sheffield ...	July 2, 1872.
26	Hay, J., jun., Bebside Col., Cowpen, Northumberland	Sept. 4, 1869.
27	Heckels, W. J., Wearmouth Colliery, Sunderland ...	May 2, 1868.
28	Hedley, E., North Seaton Colliery, near Morpeth ...	Dec. 2, 1871.
29	Hedley, J. J., Medomsley, Burnopfield	April 6, 1872.
30	Hedley, J. L., Monkwood Colliery, near Chesterfield...	Feb. 5, 1870.
31	Heslop, C., Upleatham Mines, Marske	Feb. 1, 1868.
32	Hodgson, J. W., South Derwent Colliery, Annfield Plain, near Burnopfield	Feb. 5, 1870.
33	Hughes, H. E., Killingworth Col., near Newcastle ...	Nov. 6, 1869.
34	Hunter, J., jun., East Hetton Colliery, Ferryhill ...	Mar. 6, 1869.
35	Hutton, J. A., Killingworth Colliery, near Newcastle	Sept. 4, 1869.
36	Hyslop, J. S., Belmont Mines, Guisboro'	April 1, 1871.
37	Jepson, H., Durham	July 2, 1872.
38	Joseph, D., Ty Draw, near Pontypridd, So. Wales ...	April 6, 1872.
39	Kyrke, R. H. V., 11, Albert Terrace, Wigan	Feb. 5, 1870.
40	Lisle, J., Washington Colliery, Co. Durham	July 2, 1872.
41	Longbotham, J., Consett Colls., Leadgate, Co. Durham	May 2, 1868.
42	Marley, J. W., North Brancepeth Col., near Durham	Aug. 1, 1868.
43	Mills, M. H., North Seaton Colliery, Morpeth... ...	Feb. 4, 1871.
44	Moore, R. W., Wanley Street, Waterloo, Blyth ...	Nov. 5, 1870.
45	Moore, W., jun., Hetton Collieries, Fence Houses ...	July 2, 1872.

		ELECTED.
46	Moses, W., Lumley Colliery, Fence Houses	Mar. 2, 1872.
47	Pamely, C., Radstock Coal Works, near Bath	Sept. 5. 1868.
48	Panton, F. S., 6, Thornhill Terrace, Sunderland ...	Oct. 5, 1867.
49	Parland, J. J., Burnopfield, Gateshead	May 4, 1872.
50	Place, Thomas, No. Hetton Collieries, Fence Houses ...	April 2, 1870.
51	Potter, A. M., Heaton Hall, Newcastle	Feb. 3, 1872.
52	Price, J. R., Wigan Coal and Iron Co., Wigan ...	Aug. 7, 1869.
53	Reed, R. B., Newbottle Colliery, Fence Houses ...	Mar. 5, 1870.
54	Ritson, W. A., Towneley Colliery, Blaydon-on-Tyne ...	April 2, 1870.
55	Robson, J. M., 11, Belhaven Terrace, Glasgow ...	Dec. 5, 1868.
56	Sheraton, Frederick, Silksworth Colliery, near Sunderland	June 6, 1868.
57	Sopwith, T., jun., Nunnery Colliery Offices, Sheffield ...	Nov. 2, 1867.
58	Sparkes, C., 76, Linthorpe Road, Middlesbro'	Sept. 5, 1868.
59	Stratton, T. H. M., Jobs Hill Colliery, near Crook ...	Dec. 3, 1870.
60	Vernon, J. O., Villa de St. George, Newcastle... ...	Sept. 7, 1867.
61	Walker, G. B., East Rainton, Fence Houses	Dec. 2, 1871.
62	White, J. F., M.E., Wakefield	July 2, 1872.
63	Wild, J. G., Peases' W. Waterhouses Coll., by Durham	Oct. 5, 1867.
64	Wilson, W. B., Killingworth Colliery, Newcastle ...	Feb. 6, 1869.

List of Subscribing Collieries.

Owners of East Holywell Colliery, Earsdon, Northumberland.
" Haswell Colliery, Fence Houses.
" Hetton Collieries, Fence Houses.
" Kepier Grange Colliery, by Durham
" Lambton Collieries, Fence Houses (Earl Durham).
" North Hetton Colliery, Fence Houses.
" Rainton Collieries (Earl Vane).
" Ryhope Colliery, near Sunderland.
" Seghill Colliery, Northumberland.
" South Hetton and Murton Collieries, Fence Houses.
" Stella Colliery, Ryton, Newcastle-upon-Tyne
" Throckley Coal Company, Newcastle.
" Wearmouth Colliery, Sunderland.
" Whitworth Colliery, Ferry Hill.

Rules.

1.—The objects of the North of England Institute of Mining and Mechanical Engineers are to enable its members to meet together to discuss the means for the Ventilation of Coal and other Mines, the Winning and Working of Collieries and Mines, the Prevention of Accidents, and the Advancement of the Sciences of Mining and Engineering generally.

2.—The North of England Institute of Mining and Mechanical Engineers shall consist of three classes of members, namely :—Ordinary Members, Life Members, and Honorary Members, with a class of Students attached.

3.—Ordinary and Life Members shall be persons practising as Mining or Mechanical Engineers, and other persons connected with or interested in Mining and Engineering.

4.—Honorary Members shall be persons who have distinguished themselves by their literary or scientific attainments, or who have made important communications to the Society, Government Mining Inspectors during the term of their office, and the Professors of the College of Physical Science, Newcastle-upon-Tyne, during their connection with the said College.

5.—Students shall be persons who are qualifying themselves for the profession of Mining or Mechanical Engineers, and such persons may continue Students until they attain the age of 23 years.

6.—The Annual Subscription of each Ordinary Member shall be £2 2s., payable in advance, and the same is to be considered due and payable on the first Saturday of August in each year, or immediately after his election.

7.—All persons who shall at one time make a donation of £20 or upwards shall be Life Members.

8.—The Annual Subscription of each Student shall be £1 1s., payable in advance, and the same is to be considered due and payable on the first Saturday of August in each year, or immediately after his election.

9.—Each Subscriber of £2 2s. annually (not being a member) shall be entitled to a ticket to admit two persons to the rooms, library, meetings, lectures, and public proceedings of the Society; and for every additional £2 2s., subscribed annually, two other persons shall be admissible up to the number of ten persons; and each such Subscriber shall also be entitled for each £2 2s. subscription to have a copy of the Proceedings of the Institute sent to him.

10.—Persons desirous of being admitted into the Institute as Ordinary Members, Life Members, or Students, shall be proposed by three Members, and as Honorary Members by at least five Members. The nomination shall be in writing and signed by the proposers (see Form A), and shall be submitted to the first General or Special Meeting after the date thereof. The name of the person proposed shall be exhibited in the Society's room until the next General or Special Meeting, when the election shall be proceeded with by ballot, unless it be then decided to elect by show of hands. A majority of votes shall determine every election. Notice of election shall be sent to each Member or Student within one week after his election, on Form B, enclosing at the same time Form C, which shall be returned by the Member or Student, signed, and accompanied with the amount of his annual subscription, within two months from the date of such election, which otherwise shall become void.

11.—The Officers of the Institute shall consist of a President, six Vice-Presidents, and eighteen Councillors, who, with the Treasurer and Secretary (if Members of the Institute), shall constitute a Council for the direction and management of the affairs of the Institute. The President, Vice-Presidents, and Councillors shall be elected at the Annual Meeting (except in case of vacancies), and shall be eligible for re-election, with the exception of any President or Vice-President who may have held office for the three immediately preceding years, and such six Councillors who may have attended the fewest Council Meetings during the past year; but such Members shall be eligible for re-election after being one year out of office.

12.—All Members shall be at liberty to nominate, in writing, and send to the Secretary, not less than fourteen days prior to the Annual or Special Meeting, a list of Ordinary and Life Members who are considered suitable to fill the various offices, such list being signed by the nominators. A list of the persons so nominated and of the retiring Officers, indicating those who are ineligible for re-election (see Form G), shall constitute a balloting list, and shall be posted at least seven days previous to the Annual or Special Meeting, to all Members of the Institute, who may erase any name or names from this list, and substitute the name or names of any other person or persons eligible for each respective office; but the number of persons on the list, after such erasure or substitution, must not exceed the number to be elected to the respective offices as above enumerated. The balloting papers must be returned through the post, addressed to the Secretary, or be handed to him, or to the Chairman of the Meeting, so as to be received before the hour fixed for the election of officers. The Chairman shall then appoint four Scrutineers, who shall receive the balloting papers, and shall sign and hand to the Chairman of the Meeting a list of the elected Officers, after destroying the papers. Those papers which do not accord with these directions shall be rejected by the Scrutineers. The votes for any Members who may not be elected Vice-Presidents shall count for them as Members of the Council.

In case of the decease or resignation of any Officer or Officers, notice thereof shall be given at the next General or Special Meeting, and a new Officer or Officers elected at the succeeding General or Special Meeting, in accordance with the mode above indicated.

13.—At meetings of the Council, five shall be a quorum, and the minutes of the Council's proceedings shall be at all times open to the inspection of the Members of the Institute. The President shall be *ex-officio* Chairman of every committee.

14.—All past Presidents shall be *ex-officio* Members of the Council so long as they continue Members of the Institute, and Vice-Presidents who become ineligible from having held office for three consecutive years, shall be *ex-officio* Members of the Council for the following year.

15.—A General Meeting of the Institute shall be held on the first Saturday of every month (except in January and July) at two o'clock; and the General Meeting in the month of August shall be the Annual Meeting, at which a report of the proceedings, and an abstract of the accounts of the previous year, shall be presented by the Council. A Special Meeting of the Institute shall be called whenever the Council may think fit, and also on a requisition to the Council, signed by ten or more Members.

16.—Every question, not otherwise provided for, which shall come before any Meeting of the Institute, shall be decided by the votes of the majority of the Ordinary or Life Members then present.

17.—The Funds of the Society shall be deposited in the hands of the Treasurer, and shall be disbursed or invested by him according to the direction of the Council.

18.—All papers shall be sent for the approval of the Council at least twelve days before a General Meeting, and after approval shall be read before the Institute. The Council shall also direct whether any Paper read before the Institute shall be printed in the Transactions, and notice shall be given to the writer within one month after it has been read, whether it is to be printed or not.

19.—The Copyright of all Papers communicated to, and accepted for printing by the Council, shall become vested in the Institute, and such communications shall not be published for sale or otherwise, without the written permission of the Council.

20.—All proofs of discussion, forwarded to Members for correction, must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

21.—The Institute is not, as a body, responsible for the facts and opinions advanced in the Papers which may be read, nor in the discussions which may take place at the Meetings of the Institute.

22.—Twelve copies of each Paper printed by the Institute shall be presented to the author for private use.

23.—Members elected at any Meeting between the Annual Meetings shall be entitled to all Papers issued in that year, as soon as they have signed and returned Form C, and paid their subscriptions.

24.—The Transactions of the Institute shall not be forwarded to Members whose subscriptions are more than one year in arrear.

25.—Any person whose subscription is two years in arrear, that is to say, whose arrears and current subscription shall not have been paid on or before the first of August, shall be reported to the Council, who shall direct application to be made for it according to Form D, and in the event of it continuing one month in arrear after such application, the Council shall have the power, after suitable remonstrance by letter in the form so provided (Form E), of erasing the name of the defaulter from the register of the Institute.

26.—No duplicate copies of any portion of the Transactions shall be issued to any of the Members unless by written order from the Council.

27.—Invitations shall be forwarded by the Secretary to any gentleman whose presence at the discussions the Council may think advisable, and strangers so invited shall be permitted to take part in the proceedings. Any Member of the Institute shall also have power to introduce two strangers (see Form F) to any of the General Meetings of the Institute, but they shall not take part in the proceedings, except by permission of the meeting.

28.—No alteration shall be made in any of the Laws, Rules, or Regulations of the Institute, except at the Annual General Meeting, or at a Special Meeting for that purpose, and the particulars of every such alteration shall be announced at a previous General Meeting, and inserted in its minutes, and shall be exhibited in the Room of the Institute fourteen days previous to such Annual or Special Meeting, and such Meeting shall have power to adopt any modification of such proposed alteration of, or addition to, the Rules.

APPENDIX.

[FORM A.]

Name in full—Mr.
Designation or Occupation
Address
being desirous of admission into the North of England Institute of Mining and Mechanical Engineers, we, the undersigned, propose and recommend that he shall become a thereof.

Proposed by { ______ ______ ______ } Signatures of three Members.

Dated 18

[FORM B.]

Sir,—I beg to inform you that on the day of you were elected a of the North of England Institute of Mining and Mechanical Engineers, but in conformity with its Rules your election cannot be confirmed until the enclosed form be returned to me with your signature, and until your first annual subscription be paid, the amount of which is £

If the first subscription is not received within two months from the present date, the election will become void, under Rule 10.

I am, Sir,

Yours faithfully,

Secretary.

Dated 18

[FORM C.]

I, the undersigned, being elected a of the North of England Institute of Mining and Mechanical Engineers, do hereby agree that I will be governed by the regulations of the said Institute as they are now formed, or as they may hereafter be altered; that I will advance the objects of the Institute as far as shall be in my power, and will not aid in any unauthorised publication of the proceedings, and will attend the Meetings thereof as often as I conveniently can; provided that whenever I shall signify in writing to the Secretary, that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand this day of 18

[FORM D.]

18

Sir,—I am directed by the Council of the North of England Institute of Mining and Mechanical Engineers to draw your attention to Rule 25, and to remind you that the sum of £ of your annual subscriptions to the funds of the Institute remains unpaid, and that you are in consequence in arrear of subscription. I am also directed to request that you will cause the same to be paid without further delay, otherwise the Council will be under the necessity of exercising their discretion as to using the power vested in them by the Rule above referred to.

I am, Sir,

Yours faithfully,

Secretary.

[FORM E.]

18

Sir,—I am directed by the Council of the North of England Institute of Mining and Mechanical Engineers to inform you, that in consequence of non-payment of your arrears of subscription, and in pursuance of Rule 25, the Council have declared, by special vote, on the day of 18 , that you have forfeited your claim to belong to the Institute, and your name will be in consequence expunged from the Register, unless payment is made previous to

But notwithstanding such forfeiture, I am directed to call upon you for payment of your arrears, amounting to £

I am, Sir,

Yours faithfully,

Secretary.

[FORM F.]

Admit

of

to the Meeting on Saturday, the

(Signature of Member or Student)

The Chair to be taken at Two o'clock.

I undertake to abide by the Regulations of the North of England Institute of Mining and Mechanical Engineers, and not to aid in any unauthorized publication of the Proceedings.

(Signature of Visitor)

Not transferable.

[FORM G.]

BALLOTING LIST.

Ballot to take place at the Meeting of ______ 18 ______ at Two o'clock.

PRESIDENT—One Name to be returned.

† ______ Retiring President.

* ______ ______ ______ New Nominations.

VICE-PRESIDENTS—Six Names to be returned.

The Votes for any Members who may not be elected as Vice-Presidents will count for them as other Members of the Council.

† ______ ______ ______ ______ ______ ______ Retiring Vice-Presidents.

* ______ ______ ______ New Nominations.

COUNCIL—Eighteen Names to be returned.

______ ______ ______ † ______ † ______ ______ ______ ______ † ______ ______ ______ † ______ † ______ † ______ ______ Retiring Councillors.

* ______ ______ ______ ______ New Nominations.

Rule XII.—Relative to the Election of the Officers of the Institute.

______

______

______

______

______

† These Gentlemen are ineligible for re-election.
* These Gentlemen are not on the Council for the present year.

Names substituted for any of the above are to be written in the blank spaces opposite those they are intended to supersede.

Any List returned with a GREATER NUMBER than
ONE PRESIDENT,
SIX VICE-PRESIDENTS,
EIGHTEEN COUNCILLORS,
Will be rejected by the scrutineers as informal, and the Votes will, consequently, be lost.

ADVERTISEMENT.

THE Institute is not as a body responsible for the facts and opinions advanced in the Papers read, and in the Abstracts of the Conversations which occurred at the Meetings during the Session.

NORTH OF ENGLAND INSTITUTE

OF

MINING AND MECHANICAL ENGINEERS.

GENERAL MEETING, SATURDAY, SEPTEMBER THE 2ND, 1871, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

E. F. BOYD, ESQ., PRESIDENT OF THE INSTITUTE, IN THE CHAIR.

The SECRETARY read the minutes of the previous meeting, and also the minutes of the Council.

The following gentlemen were then elected:—

MEMBERS—

LUCIEN GUINOTTE, Directeur des Charbonnages de Mariemont et de Bascoup, Mons.
ALPHONSE BRIART, Ingénieur en chef des Charbonnages de Mariemont et de Bascoup, Mons.
J. GILLE, Ingénieur au Corps Royal de Mines, Mons.
CHARLES BLAGBURN, Engineer, 3, St. Nicholas Buildings, Newcastle.
H. F. SWAN, Shipbuilder, Jesmond, Newcastle.
R. R. REDMAYNE, Chemical Manufacturer, Gateshead.
JOHN G. SWAN, Ironmaster, Cargo Fleet, Redcar.
A. FREIRE-MARRECO, Analytical Chemist, Newcastle-on-Tyne.
ARCHIBALD STEVENSON, South Shields.
HENRY COXON, Quay, Newcastle-on-Tyne.
THOMAS HODGKIN, Banker, Newcastle-on-Tyne.
GEORGE FENWICK, Banker, Newcastle-on-Tyne.
JAMES MCINTYRE, Shipbuilder, Jarrow.
JOHN WILLIAMSON, Chemical Manufacturer, South Shields.
JONATHAN PRIESTMAN, Coal Owner, Newcastle.
T. MACDOUGALL SMITH, C. & M. E., London.
FRANCIS CHARLTON, C.E., Newcastle.
JAMES BLACK, Jun., Ironfounder, South Shields.

In consequence of the small attendance of members, the papers announced for reading were postponed till the next meeting.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, OCT. 7, 1871, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

E. F. BOYD, Esq., President of the Institute, in the Chair.

The Secretary read the minutes of the last meeting, and reported the proceedings of the Council.

The following gentlemen were then elected:—

Members—
Utrick A. Ritson, 6, Queen Street, Newcastle.
Hilton Philipson, 8, Queen Street, Newcastle.
Thomas Barnes, Quay, Newcastle.
T. B. Winter, Grey Street, Newcastle.
R. R. Dees, Pilgrim Street, Newcastle.

Student—
M. W. Brown, 8, Belgrave Terrace, Newcastle.

Mr. Crone then read a paper, by Mr. Henry Lewis, "On the Method of Working Coal by Long-Wall, at Annesley Colliery, Nottinghamshire."

ON THE METHOD OF WORKING COAL BY LONG-WALL, AT ANNESLEY COLLIERY, NOTTINGHAMSHIRE.

By HENRY LEWIS.

Several papers have been read before the North of England Institute of Mining and Mechanical Engineers, on the working of coal by long-wall, and, as they differ materially from the method adopted and found to answer at Annesley Colliery, the writer hopes that those members engaged in the working of deep collieries may derive some benefit from the following remarks.

In many of the coal-fields in England the crop or seams of coal near the surface are worked out, and deep seams have to be reached at a serious outlay, sometimes at a cost of one hundred thousand pounds or more; and as a colliery with a capital of this magnitude has occasionally to compete with others in the same district, where the coal has been won at half the cost, it behoves the mining engineer to study if he cannot, by a more enlightened method of working the coal than in a deep seam, bring it cheaper to bank than coal of the same description and quality where less capital has been expended.

No doubt much may be saved in reducing the quantity of heading, in using less propwood, fewer cuttings, and the leaving of pillars, and above all in diminishing the quantity of small coal or slack; such items as these make the difference between a paying and a non-paying colliery.

Many a splendid seam of deep coal is worked at a great expense, by following out the usual method of getting coal at a short distance from the surface.

In a district the selling price of a number of collieries is nearly the same, and is regulated according to the demand, so that much depends upon working economically.

The seam worked at Annesley is four hundred and sixty-three yards from the surface, and is known by the name of the Top hard. It covers a large area of Nottinghamshire, Derbyshire, and Yorkshire, and is not only a good house-coal but one of the best for locomotive engines and blast furnaces; the thickness, however, is very irregular, and is found to diminish gradually as it gets more eastward.

The writer is of opinion that in all deep collieries working coal by long-wall, after a sufficient pillar has been left for the support of the shafts, it is better to take all the coal out (see Plate II.), than to leave pillars (see Plate I.). This is obvious to any practical engineer, because the pressure at say 500 yards amounts to something like 1,500 lbs. to the square inch, and any weak point such as **A** on Plate I. becomes very much crushed, and causes an extra quantity of timber to be used for the support of the roof.

Plate I. shows the system first tried, and the quantity of heading was found not only very costly, but the 60 yards pillars left were worse than useless in supporting the main roads; the gates through the pillars stood well until the face of the stall had advanced far enough to get a weight, and then the crushing of the timber, the grinding of coal, and the breaking down of the roof in the gates, were so great, that many of the roads had to be raised above the coal, and although bars and props were set every yard, they could not withstand the constant squeezing that went on, but had to be frequently renewed, and in working these pillars back, they did not yield more than thirty per cent. of large coal.

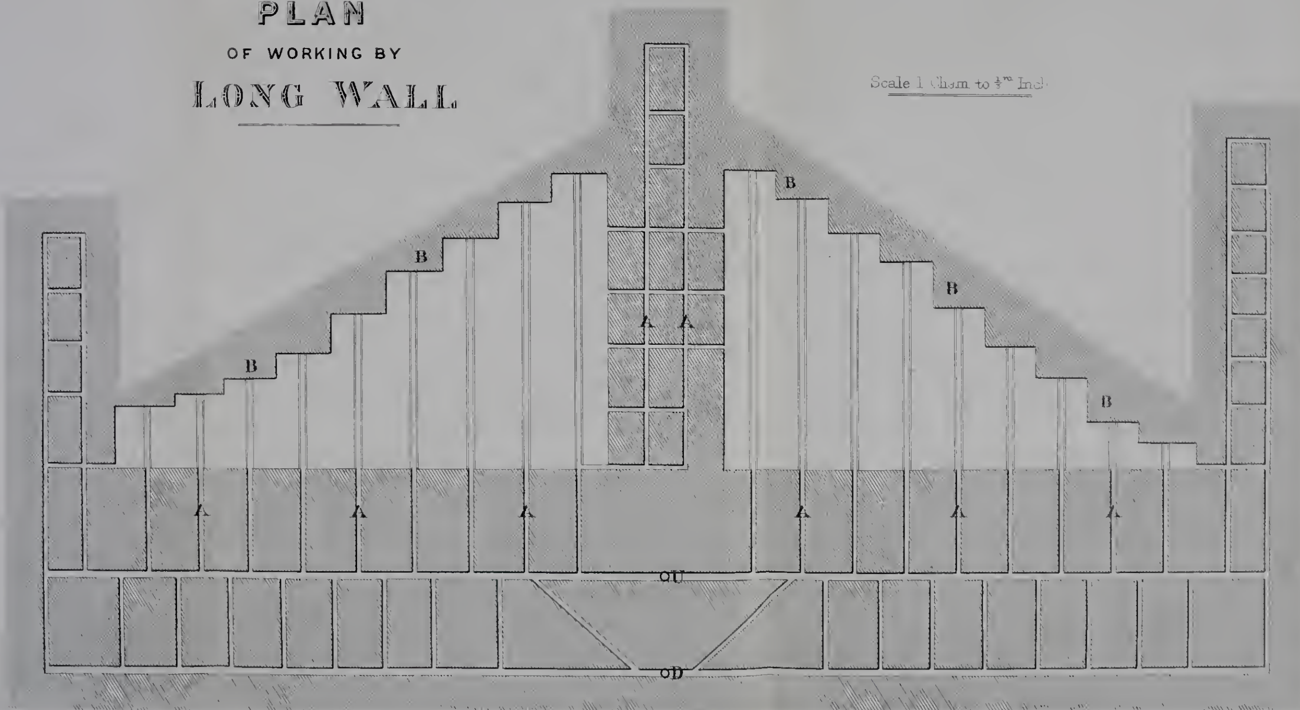
It is a mistake to suppose that when one stall leads another the face is more protected from the crush of the overlying strata; it is found in practice that such corners as **B** on Plate I. are very much crushed, and prevent the roof settling in an easy manner upon the goaf, thus causing the stalls to be oftener on the weight, than is the case when coal is worked upon the principle shown in Plate II.; it is also far more difficult and expensive to ventilate where the stalls lead one another, as an airway has to be packed wherever there is a fast end, and these cuttings or windings are a continual source of expense, as the roof will be constantly breaking down, or the floor lifting; in fact it is frequently impossible to keep them open, consequently a fast end in a stall is seldom properly ventilated.

The writer maintains that in working coal by long-wall at great depths, the extra weight of strata ought to be an assistance instead of a drawback in getting the coals, if the line of face be properly arranged. Stalls directly upon the face will not do, as too much small coal is made; they must either be on the end or half-end and face; the latter is found to answer best at Annesley Colliery, although part of the workings are on the end; blasting is scarcely known; the overlying strata act sufficiently as a lever in bringing down the coals after they are holed; and although this is the case, eighty per cent. of large coal is realised, which will compare favourably with most places in the Midland Counties.

It is found in practice with a long length of workings in a straight

PLAN
OF WORKING BY
LONG WALL

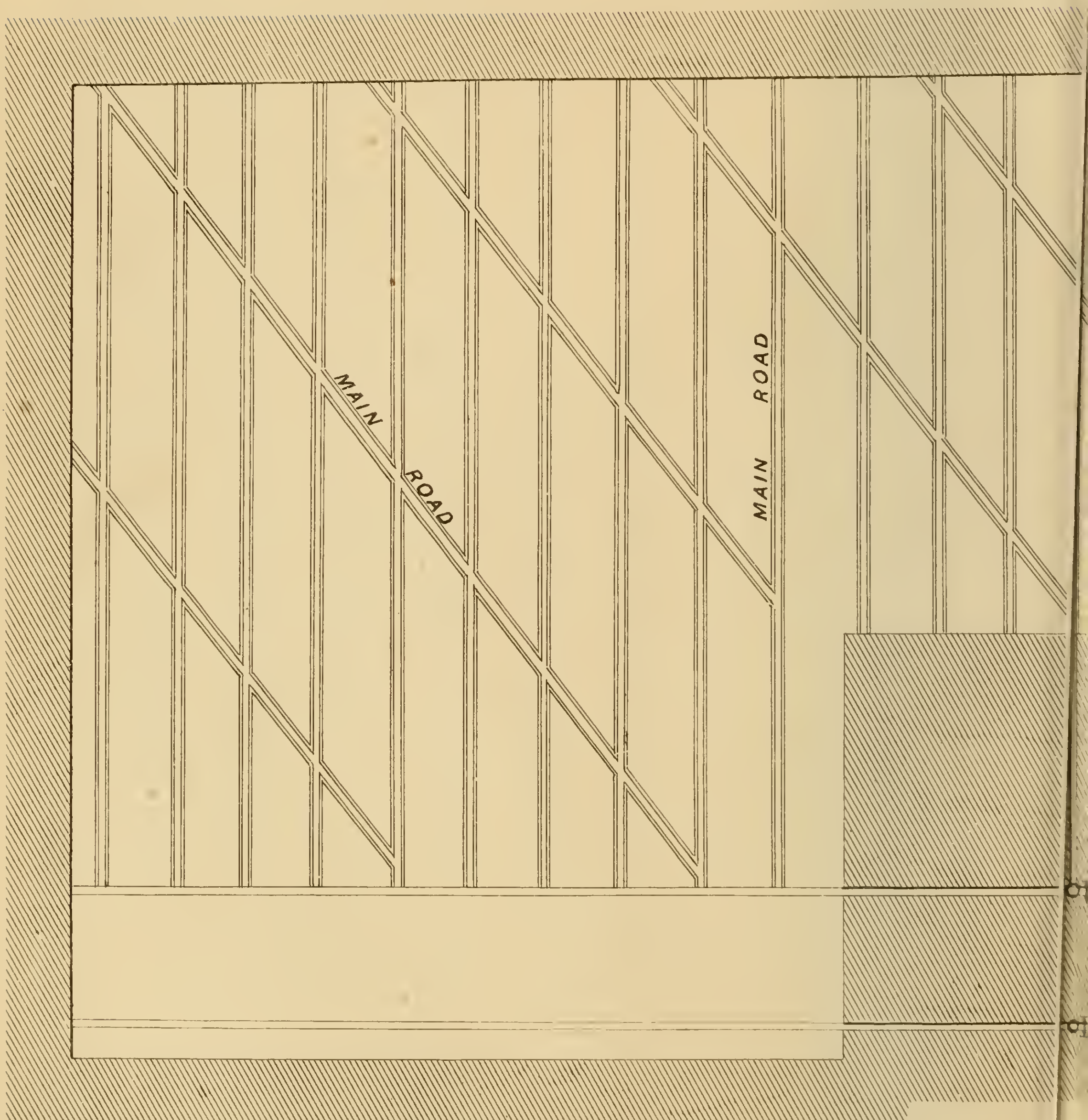
Scale 1 Chain to 1/3rd Inch



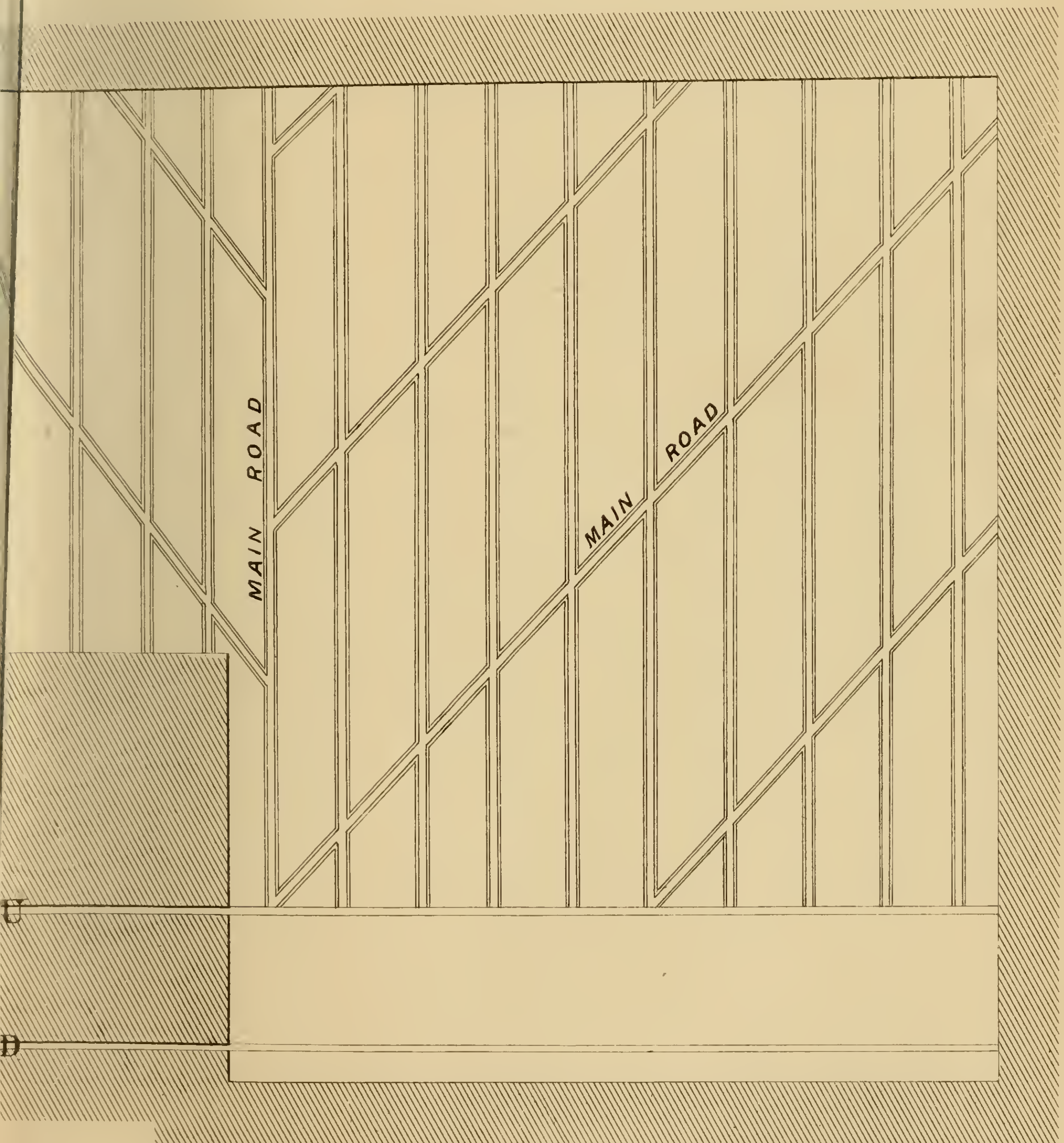
PLAN

OF WORKING BY

LONG WALL



Scale 1 Chain to $\frac{1}{4}$th Inch.



line moving every day, the weight seldom, if ever, crushes to any extent, but as a rule, bends down and settles gradually upon the pack two or three yards from the face. The packs for the support of the roof should be kept well built up, and as near the face as practicable. At Annesley there is close upon a thousand yards of face on a thread, and although such is the case the roof never breaks down in the benks unless the stalls are allowed to stand.

There is also a great saving in timber where there is a face of coal moved every day, as the weight seldom, if ever, crushes the wood, if the back rows of props are removed as the face of the stalls advances. The back rows of timber should never be allowed to be more than six feet from the face, and particular care should be taken that they are removed, as the safety of the stalls depends to a certain extent upon this, which if neglected very often throws the weight forward instead of allowing it to sink gradually upon the goaf. Timber in any case is only of service either in the gate roads or stalls, until the packs for the support of the roof are formed; when this is done all timber should be at once removed, so as to allow the overlying strata to settle easily upon the packs which gradually become perfectly solid.

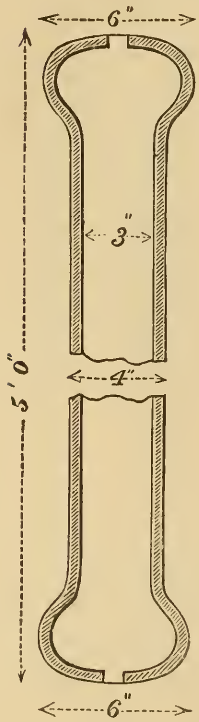
In working coal giving off gas by long-wall, the writer considers a long length of face safer than dividing it into districts by pillars, as gas as a rule is given off constantly from breaks, or issues from the coal wherever there is the least resistance, and it is wrong to suppose that there is more danger by this method of working because of the large area of goaf room. Goaf there certainly is, but open space little or none, as everything becomes comparatively close a few yards from the face, and there cannot be those obstructions to the ventilation where the face is in a straight line, as when, to a certain extent, dependence is placed upon airways packed up to a rib side, which airways are necessary, if the stalls are worked with a fast end; the air can also be as easily divided into splits as where pillars are left to divide districts; a split of air should never ventilate more than three hundred yards of face, and be regulated according to the number of men working.

PILLARS TO DIVIDE DISTRICTS.

It has been asserted by the advocates for working coal by long-wall that pillars of from one to two chains ought to be left to divide districts; this the writer has found wrong in practice, as the weight crushes and opens the joints of the coal so as to render them inadequate to keep back air or water; and where a colliery is liable to spontaneous combustion, these thin ribs are very often the cause of fire breaking out in the goaf, as they not only prevent the roof settling in a proper manner, but allow the air to work through the breaks or openings in the coal, and so cause a fire, which might be easily extinguished in a large goaf, to become serious. Many goaf-fires have originated near a rib side, in some cases causing large areas of coal to be lost, and occasionally closing a colliery for months together at a ruinous expense. It is better to have one large goaf, which, as the strata sink upon it, will settle down and become nearly as solid as the coal; these thin pillars would prevent this, and each district would never get the same amount of pressure upon the goaf, so that openings would be formed in the roof, which in some cases would fill with gas, and so become a source of danger. There is also another reason why the writer considers the use of pillars to divide districts a mistake. In a large colliery, working a thin seam, several districts would have to be formed, and a large amount of coal would be lost, as the coal in these thin ribs would be so crushed that it would not pay to work them back.

TIMBER.

In working by long-wall at great depths, timber is very often an expensive item; in some cases the cost per ton will be as much as sixpence, and in a well regulated colliery, working the same seam, it will not cost more than twopence, or even less, per ton.

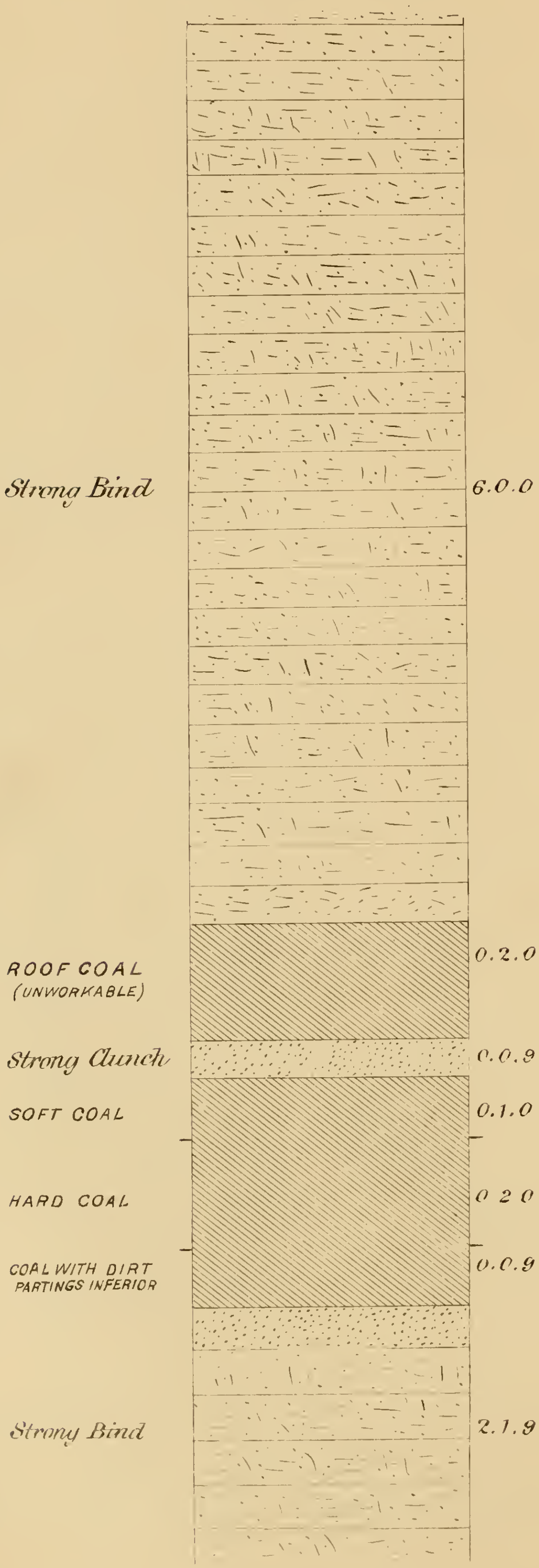


At Annesley great care is taken along the face of the stalls to build packs, not more than nine feet apart, of the clunch overlying the coal; these are kept well built up to the roof, are never more than six or seven feet from the face, and as the roof settles upon them, the back row of props is withdrawn. No wooden chocks are used, as the stone packs answer the same purpose, and never have to be removed. When this system is properly carried out, it is seldom that a prop is broken, for they are taken out as soon as the packs are brought forward; the packs taking the weight and relieving the timber. There is a great saving when this is properly attended to; and a row of props will last some weeks.

Cast iron props (see margin) are only used at the gate ends, and are set about four feet apart; only three on each side of the road are allowed, and they are taken out as soon as the packs are formed; they weigh 140 lbs., and cost about seven shillings and sixpence each; they are a

SECTION OF TOP HARD SEAM

ANNESLEY.



great saving and answer well, as being set under a coal roof, they enter and allow the roof to settle. They are easily removed after having had pressure on them for sometime.

It is a mistake, and one the writer has seen at several collieries working coal by long-wall, to attempt to keep up a heavy weight of broken roof by means of timber. It entails a lasting expense, as the timber must be renewed from time to time as the roof sinks, and no amount of wood will prevent this when once the coal is taken out. There is also a risk of human life, as a prop accidentally knocked out may cause tons of roof to fall.

LENGTH OF STALLS.

Much has been written about the proper length of stalls; from the writer's experience, they should not be longer than from twenty to thirty yards, as the face ought in any case to advance every day. There are several reasons why this should be done. First, to prevent the pressure from grinding to a certain extent upon the face of the stall, thus causing an extra quantity of small coal to be made; and secondly, to work a given area as quickly as possible; as it must be evident to every one, that the longer a district is being worked the more expensive it is, for height has to be kept in the gates at no small cost, and this in a quickly worked district will be avoided to a great extent. Ripping the gates for height, and maintaining it, is the most serious item the workers by long-wall have to contend against, and generally averages from threepence to sixpence per ton on the cost of working; of course, all depends upon the nature of the roof and floor, as in some cases the packed roads will not stand until the roof and floor meet.

At Annesley the hard coal (Plate III.) gives a height of 6 feet 6 inches, which is found sufficient to enable the stalls to be advanced 150 yards without taking any roof down for height, except in the principal gates. Main roads (see Plate II.) are carried 300 yards from each other, and are packed 10 feet wide, the packs being formed of the strong clunch lying immediately above the coal. In all gates the roof coal is taken down, but the roads, where no ripping is done, are cut off by a stall as soon as they are too low for proper loading to come out. At some collieries gates are carried 300 or 400 yards before they are cut off, and it must be evident to every one, where such is the case, that a large amount of money must be expended in keeping such a length of road in repair. The fewer roads the better, as by the plan adopted at Annesley, cutting off and opening out a new stall costs a mere trifle, compared with what the ripping would cost, if the roads were carried only twice the distance. The method of cutting faces off is by taking a stall at an angle of 40° or 50°; the latter is the best angle, as the line of cleavage from pack to pack is shortened, and there is not the same amount of risk of the roof breaking down. The method of doing this will be easily seen in Plate II.

It is now universally acknowledged that engine-power for the haulage of coal is far cheaper than any other method, whether by endless-chains, endless-ropes, or tail-ropes.

The writer is of opinion that it is only a question of time before compressed air for working underground engines will entirely supersede steam. In deep mines, where the natural temperature of the coal is over 70°, there requires no argument to prove the advantage the latter method has over steam, especially where the engines have to be placed many hundred yards inbye to haul a large area of dip coal.

In this brief paper the writer has endeavoured to show, that at Annesley there is sufficient proof that the fewer pillars left in working coal at great depths the better; and, although in some districts large coal is not of the same importance as it is in the Midland Counties, still, with the system adopted, there is a great saving, not only in getting the coal, but also in heading, timber, maintenance of roads, rails, etc., and not the same amount of crushing upon the face as there was when the mode of working shown in Plate I. was being carried out.

In conclusion, the writer hopes that some of his remarks will elicit from other members of the Institute their experience in working coal at great depths by other methods. There is no doubt more economy to be effected in working deep mines, and the destruction and waste of getting coal in the old-fashioned way must be done away with, if deep winnings are to be advantageously worked.

The PRESIDENT was sure that the meeting would agree with him, that this very important subject could not be too often brought before their notice. He thought the discussion had better be postponed until the paper was printed, in order that the members might be able to acquaint themselves thoroughly with the system which the writer advocated. There would be three or four very important points to discuss; for instance, whether the system would allow of the wall being carried in a line with the cleat of the coal; the nature of the stone roof which is the best adapted for the long-wall; the best and most easy method of ventilation; whether it is best to leave any ribs of coal along with the gateways; whether these ribs produce unnecessary pressure downwards; the advantage of using the kind of prop Mr. Lewis alluded to; did these props, which were of metal, sink into the roof, and were they not difficult to draw out again, and so increase the expense; whether the use of chocks, which had been introduced very much lately in the north, might not be a very good substitute for them; the best length for the gateways; the necessity of long gateways; and the comparative cost of making new ones. These were a few of the items the discussion of which they might postpone until the paper was printed, and the author could be present.

The other subject he had to bring before their notice this morning was Mr. W. Warington Smyth's paper "On the Boring of Pit Shafts in Belgium by Messrs. Kind and Chaudron's Method." He (the President) was very sorry to observe the absence of two gentlemen (Mr. Daglish and Mr. Coulson), who would have been very much interested in this discussion, which on this account he thought worth while continuing at another meeting. Mr. Daglish was laying out one of the most expensive winnings they had in the county of Durham. Mr. Coulson, they all knew, was continually employed in sinking pits—more so, perhaps, than any other man in the district; and any question he would have asked, would have been very much to the point. In opening the discussion, he would briefly call their attention to a few items upon which he desired information. Was there any vibration of the chisels and cutter bar in the shaft? Again, was there any difficulty in boring the pit vertically? Mr. Steavenson, he thought, asked this question at the last meeting, but he considered that it had hardly been sufficiently answered at the time. Again, he would like some additional information respecting the system of floating the tubbing by using false bottoms, and how far this required to be regulated by operations on the surface? The next item seemed to be the mode of filling up the space outside the tubbing by beton or concrete—whether there was any difficulty in inserting it, and whether it became sufficiently solid to answer the purpose for which it was introduced? Then, as to the weight of the tubbing, and the number of atmospheres of pressure on the different series of rings? Then, as to the cost of labour—whether the comparative cost of labour on the Continent did not interfere very much with the comparative economy of sinking by this means, and by the ordinary means? Then, there was the question of provision for pumping, in case of leakage when the tub was once fixed, or expected to be fixed, to prevent any influx of water in the shaft;

whether the tubbing was always perfect, and whether any leakage required engine power to take it out? And then there was Mr. Daglish's question, whether there was any difficulty in determining under water, with any degree of certainty, the position of the bed-plate upon which the whole of this massive tubbing was to be founded? These were a few of the items upon which he hoped Mr. W. Smyth would give some additional information.

Mr. Smyth, knowing that many gentlemen would like further information on this subject, wrote recently to M. Chaudron to ask him to attend the meeting, but that gentleman was unfortunately in bad health and unable to leave Brussels at present. He had, however, requested MM. Javal and Chastelain, who were now present, to be his substitutes. His friend, M. Javal, was one of those engineers who attempted some years ago to put down shafts in the difficult district of the Moselle, in which this system of Messrs. Chaudron had been successfully applied. M. Javal, he thought, would admit that there he had made a great and very expensive failure; but he would assure them that he, with others, had profited in making this failure, and had become a convert to, and an authority upon, the new method which in this particular district has proved so successful; and when he introduced the other gentleman, M. Chastelain, as the engineer under whose immediate direction the Hôpital sinking was carried out, they would see that he was the highest authority which they could obtain upon matters of detail which had been omitted from his short paper. These details had been omitted for two reasons, first, because M. Chaudron himself had very fully described them in various publications; and second, because it had struck him that a fair criticism of them, and a full understanding of their advantages over other methods of detail, could scarcely be arrived at unless in the presence of gentlemen, who, like his friends, had gone practically through the whole of the operations of this system of sinking.

Mr. Cooke asked whether this method was uniformly successful, and whether there were any failures? Whether sometimes, in fact, operations commenced under the system had not to be abandoned?

Mr. Smyth, in answer to Mr. Cooke, stated that M. Chaudron had sunk 11 or 12 shafts by this method, not one of which had in any way proved a failure. They had all gone steadily on; and, although there had been occasional difficulties, yet they had all turned out perfectly water-tight in the end, and all of them may be looked upon as perfect instances of success.

Mr. Douglas observed, with reference to a point which the President had adverted to, that, in the ordinary method of tubbing pursued in this country, they found it often the case that the water did penetrate in some way which they could not in the course of the working find means to stop; and since, in the method under discussion, no pumping power was prepared, to deal with this water, should it be met with, he would like to know what course would be taken if it was found the tubbing introduced did not stop it.

Mr. Smyth said, in none of those cases which have been taken up by M. Chaudron, as yet, has there been any necessity for putting up pumping power for this purpose. He introduces his tubbing of extra strength, and with an extra, and perhaps somewhat unusual, amount of care and ingenuity, and as far as his undertakings have gone there appears to have been no leakage. In one instance a portion of the tubbing was fractured, and it had to be patched, but the whole of the details as to how that leak was stopped, and how, ultimately, there was no necessity whatever for pumping power, were given in a paper by M. Chaudron. However, it was obvious that, if leaks should take place, it would be necessary in such case to erect pumping power; but the chances were, that in such an event it would be merely a pumping engine sufficient to cope with an ordinary leak, and not the vast amount of pumping power which would be needed under the old system, such, for instance, as that encountered in a shaft commenced in the year 1865, in the Escarpelle, in which he had to deal with 10,000 gallons of water per minute, at a depth of only twenty-five yards, and where the owners were unable to get any further in consequence of being overpowered, until they introduced this system of working under water.

Mr. G. B. Forster alluded to the question of the selection of a crib-bed. In old fashioned sinking this was always considered a most important point, which required the greatest judgment; very often if the crib-bed was selected in faulty ground, it would give rise to much trouble and difficulty, and the cribbing would have to be underset. Perhaps in Belgium the strata presented none of those liabilities to slips and faults which were observed here. He would wish to know how the bed for the cribbing was selected, and how they knew when to stop their tubbing?

Mr. Douglas—For instance, in the limestone they had considerable fissures which might reach entirely over the shaft: the introduction of tubbing under these circumstances would not, to his mind, prevent the enormous flow of water which would pass through the fissure, which, possibly, might be in the centre of the shaft. He assumed, therefore, that the method of Messrs. Kind and Chaudron would require the same amount of pumping machinery to be provided as would be necessary under the old system. These were the circumstances which he thought required to be more particularly explained by the gentlemen who had so kindly attended.

Mr. Steavenson said, it appeared to him that, in the case assumed by Mr. Douglas the ordinary tubbing would not be a success either. Very often, they knew, they had an opening running right through the centre of the shaft, which would render it impossible to tub under any circumstances.

The President—Under these circumstances you would simply have to proceed as usual, and bore still deeper.

Mr. Steavenson—If they were not successful in one case with the new system of tubbing they would be equally unsuccessful in the other with the old; therefore, the objection is no way peculiar to the system proposed by Mr. Smyth. It seemed to him that there was only one thing left for them to do, and that was to try the system in this district.

Mr. G. B. Forster was sure Mr. Smyth would see the point of his question, as to putting in the tubbing where there are fissures. When the sinking is done in the ordinary way these fissures are visible, in the new system they are not. How is it ascertained when water-tight ground is reached?

Mr. Smyth—The question which had been put was one which, of course, at once suggested itself to those conversant with the very difficult nature of the ground which had to be passed through in different places. Mr. Steavenson, he thought, had amply answered the first portion of the question. M. Chaudron would never attempt to establish a tubbing, or any foundation for it, except after boring down through any difficult fissured ground to ground which offered every appearance of being perfectly solid. Then they came to Mr. Forster's question—How could he feel sure of the ground? In the first place, where sinking of this kind had to be carried out, they had small bore-holes of the ordinary dimensions, which threw some light on the nature of the ground. In the second place, very little risk attached to districts like those of Belgium, where it was well known that, when they got down to a certain part of the measures, they entered solid strata, sufficiently free from slips to warrant the expectation, under ordinary circumstances, that there would be a water-tight bed obtainable; and he presumed also that M. Chaudron was very much assisted from the fact, that his boring tools were on such a scale that he was able to bring up large core pieces of the rocks and strata, and examine the stone so thoroughly as to its character, that there was very little chance of making any mistake on that head, unless the shaft was sunk actually in the line of fault. Such an instance as that, of course, might occur, but it would be very unlikely. M. Chastelain told him that in such cases they will generally see indications of the presence of a fault in what is brought up, and that in such cases they would go further until they found themselves in more solid ground; the whole being, to a certain extent, guided by their previous knowledge of the geological character of the ground, and, also, by what had been ascertained by means of the ordinary bore holes, or by the knowledge of the neighbouring ground from other pits, he felt sure that an effectual crib-bed might be secured with the greatest certainty. With respect to the vibration of the rods, and the verticality of the bore-holes, M. Chastelain had asked him to say that he had met with more difficulty than usual in boring the Maurage Pits, in consequence of the presence of large masses of flint. These flints in some places formed complete beds—in other places, they came in large lumps; and, in borings of large sizes (14 to 15 feet) became very difficult to pierce evenly from the large area of the cutting operations. Notwithstanding this, they had been steadily advancing, more slowly than usual it was true; but since he had the pleasure of being at the Institute on a former occasion, their sinking had advanced to within 20 metres of the depth at which it is proposed to fix the foundation of the tubbing. He thought that the best answer to any doubt, as to the possibility of securing verticality by the method proposed, was that, throughout the whole series of sinkings which M. Chaudron had undertaken, not one shaft had proved defective in this respect.

Mr. Douglas felt the full force of what Mr. Smyth had said, but with his knowledge of this district in the North of England, and of the difficulties which had to be encountered in such strata as the magnesian limestone, for instance, he would wish definitely to ask whether Mr. Smyth did not think that circumstances in this district might occur which would prevent the system being carried out, unless appliances were also prepared which would keep away the water which might pass.

Mr. Smyth—The great probability was, that in dealing with any formation, M. Chaudron would make up his mind, such as that described by Mr. Douglas, to go to the base of it and get well on to some regular bed below it, before he could establish his tubbing.

Mr. Marley thought it only right, when they were favoured by the presence of gentlemen who had come so long a distance, and who had taken a practical part in carrying out this system, that the members of the Institute should be prepared to-day to discuss this paper as far as possible in all those details upon which they wished to have information. He, therefore, hoped Mr. Smyth would excuse him, if he asked whether, after they had got their shafts down and their moss-beds perfectly water-tight, they had tested what was the actual pressure of the water upon any one of the tubs which they had completed. They had tested the metal tubs to 28 atmospheres, by way of precaution, but what was the actual and greatest pressure they had ever obtained? Next, with regard to the technical term *spoons*, for putting in what they might call the concrete behind the tubbing, he would be obliged if Mr. Smyth would give some further detail as to how this process was carried on. Again, that which he thought was *prima facie* the greatest objection to the system, was the difficulty of judging where or when they had got a proper crib-bed. Mr. Smyth, in the discussion on the last occasion, said, that with the aid of the *lazy-tongs*, M. Chaudron could discover a fissure, or even a soft part in the bed, with such certainty as to ensure success. This was considered proved, because in 10 or 11 cases they had succeeded in doing so; but still, there is the question as to whether the working of these *lazy-tongs* could always be depended on. He did not quite understand the drawing, but supposed there was some projection on these *tongs* which would slip into any fissures. He would ask if these *tongs* were relied on more than the results of the borings in the strata, and the debris which they brought up by their sludge-pump, and also why it was necessary to insert a wrought-iron tubbing outside the metal tubbing at the St. Barbe Pit, as described in page 198; and why, if it was necessary in this case, it was not so in others?

Mr. Smyth, in reference to the latter question, stated that during the process of boring the pit at St. Barbe, Ressaix, a large influx of coarse quicksand burst in upon them in such quantities, that they had not power to bore through; in order, therefore, to keep back this sand before the permanent tubbing was lowered, and in fact before the boring was completed, it was thought expedient to put in a wrought-iron tub. This effected its purpose (which was merely to hold back the sand and not to keep off the water), but the pressure of the sand bulged it in places, and they had regretted not having made it of cast iron.

The President asked if in such cases, where additional tubbing had to be put in, any means were used to enlarge the shaft, so that the permanent tubbing, which had to go inside the temporary tubbing, might have the diameter originally contemplated? In ordinary cases, where such falls of quicksand occurred, they would be able to descend the shaft, and keep the sand back by wood cribbing, which they could make of any size that might be required.

Mr. W. Smyth assured the President that there was practically no difficulty in sinking by the new process through strata which had to be previously tubbed back in a preliminary way. M. Chaudron had several times finished pits commenced on the old plan, and bored through and past the ordinary tubbing of wood and masonry left in the old works. In the case mentioned, where the quicksand had to be tubbed back, the temporary tubbing was of no great strength, since there was no weight of water to contend against, merely the weight of the sand, or rather the excess of the weight of the sand, over that of the water, and the extra tub would only make the concrete at that part somewhat thinner. With reference to the question of Mr. Marley respecting the vertical pressure on the tubbing, they had never tried any experiment to ascertain if, from gas or other causes, any of the feeders had, when confined, a greater pressure than that due to the depth of the pit. But the tubbing described, even with the concrete surrounding it, was still in point of fact "open top tubbing," and uninfluenced by any other pressure than that due to the column of water. If from any cause local pressure beyond this was brought on the water, it would simply rise outside the concrete and be absorbed in the upper strata, or flow to the surface.

Mr. Steavenson would remark, that even in the case of the cribbing put down by M. Chaudron's plan not being tight and water escaping, engines could be put up as in the ordinary mode and the water pumped out, a new crib-bed could then be made, and the faulty one under-set and made tight.

Mr. Marley thought there had been too much stress made on the absence of means of pumping, because any engineer or coal owner, preparing a large winning, would naturally prepare large winding engines, even if he did not contemplate having to pump, which winding engines could be applied for the purpose of removing any leakage of water caused by any failure which there might happen to be in the tub.

The President—Yes, large engines going on simultaneously with the ordinary process of winning, and they could be applied to pumping if found necessary.

Mr. G. B. Forster—As they are now applied, in fact.

Mr. Cooke enquired if it had been considered how the emergency could be met if a piece of tubbing at the lower part were to give way?

Mr. G. B. Forster remarked that there would be no danger of the rings breaking in putting them in, and that no pressure would come on them till the water was removed from the inside; if a leak then occurred, it could be examined in the usual way.

Mr. Smyth—M. Chastelain has reminded me that once in sinking at Ressaix, there was a bad piece of casting in the lower rings of the tubbing, which gave way when the full pressure came on, after they had put in the concrete at the back, and after they had taken out the water, and, consequently, removed the pressure from the inside of the tubbing. The damage was repaired just as an open tubbing would be repaired under other circumstances, with the water pumped out; it was afterwards found that the concrete had settled well round the outside of the tubbing, so that, under the process described, that which would have been a very fatal kind of accident, and one very difficult to cope with, was converted into a mere leak, which could be stopped without any very great trouble or expense.

The President drew attention to the other two observations of Mr. Marley, with regard to the action of the *lazy-tongs* and *spoons*, and their method of drawing the material out.

Mr. Smyth replied that M. Chastelain assured him that with the *lazy-tongs* they could tell to a nicety whether there was any roughness or inequality in the crib-bed, so that though he was not quite sure they would fall into a fissure, still, as a general rule, they could make out when the surface on which they proposed to build the tubbing was suitable.

Mr. Marley said the tongs in Mr. Smyth's drawing were more like the sharp pointed legs of a pair of compasses; and he wanted to know whether that was so, or whether they had a sort of claw, as it were, which spread out, or downwards at the end.

Mr. Smyth—The point does project out in the other direction, as

Fig. 1.

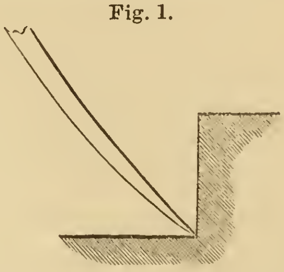
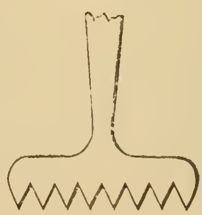


Fig. 2.



shown in Figs. 1 and 2 of the wood-cut. The sharp edge, Fig. 1, shows the transverse section of the instrument; Fig. 2 shows the broad part, like an extended hand; and the two hands on opposite sides of the shaft, being drawn close together, entangle themselves with anything rough, or any projection, or any fissure which is transverse to them.

Mr. Marley might observe that in Messrs. Mather and Platt's machine for boring—with which they were all perfectly acquainted—the principle of which was somewhat similar to the one described, he was told by Mr. Forster that instances of want of verticality had occurred. He would, therefore, like to ask if any difficulty was found in Kind and Chaudron's method of sinking when the stratification was much inclined to the horizon.

Mr. Smyth—There is no doubt whatever that this is a strong argument against the inexpensive method of boring by means of a rope instead of by rods.

Mr. Marley—Mather and Platt use a rope.

Mr. W. Smyth replied, that Mather and Platt's machine was worked by a rope, which was certainly a cheap substitute for rods, but which had the objectionable tendency to lose its verticality. In all the operations carried on by M. Chaudron neither ropes nor chains were ever used, and no deviation from the perpendicular was ever observed. In some parts the sinking had been effected through strata inclined 25 degrees to the horizon, without any tendency to deviate from the perpendicular, but M. Chastelain admits that the more inclined the stratification the more difficult it was to deal with in boring—that more care had to be taken—and the speed reduced, but with these precautions a vertical hole could always be depended on.

The President thought there had been instances in the North of England where, in going through quicksands or difficulties close to the surface, circular tubbing had been inserted in one piece; and he thought there had also been instances (and Mr. Coulson would have been able to have given them his experience on that point) where this tubbing canted before it got to the bottom of the quicksand.

Mr. Marley thought the question of verticality was more a theoretical objection than a practical one. He was afraid that some of the pits, sunk by what was termed the ordinary method, would be found wanting if their verticality were tested. With regard to metal tubbing made in one piece, he had had instances under his own inspection, where they had carried a heavy weight of metal tubbing so constructed down through sand which was in connection with tidal water; it was a very difficult process, and required great watching to keep it anything like vertical.

The SECRETARY asked whether tubbing cast in one ring had ever been used in England?

Mr. MARLEY said, he had seen it both cast in one ring and in segments bolted into one ring before being lowered down, so as to present a smooth true surface on the outside.

The PRESIDENT said, attention was called on the former occasion by Mr. Steavenson to the question of labour. He thought Mr. Smyth had very handsomely given them the comparative cost in the country where they were sinking; and he did not know that it was a question upon which they had any more observations to make, unless Mr. Steavenson himself had any.

Mr. MARLEY supposed labour would be paid at the same rate in the same country under both systems; so that he did not see that the question was material. Of course, it would not be proper to compare the cost of sinking by one mode in Belgium with the cost of sinking by the other in England.

The PRESIDENT—With regard to the false bottom, he presumed that it was so put in that it would carry as much of the weight of the tubbing as was thought proper. Was there no difficulty in keeping it air-tight?

Mr. SMYTH—It was in consequence of the very great weight and length of the tubbing which had to be lowered that M. Chaudron found himself obliged to devise some method to prevent it all hanging on the rods. In the present instance, where the tubbing weighed 800 tons, it was a very important matter indeed. By arranging this false bottom he was enabled to deal with it in such a way as never to have more than 20 or 30 tons at a time upon the lowering rods. He believed there had been no difficulty in carrying out that method thoroughly.

Mr. NEWALL asked if the President thought Mr. Marley's question as to the pressure at the bottom of the tubbing near to the cribbing was entirely answered? How did it happen that the tubbing was both open-topped and assisted by the concrete? Could it be both? If it was only a loose concrete he could understand it.

Mr. G. B. FORSTER—The concrete becomes a part of the tubbing; but it does not prevent the tubbing from getting the full weight due to the head of the water.

Mr. MARLEY quite agreed with Mr. Newall, that the question he put had not yet been answered; he was told that as the water was brought to the surface he had to calculate the pressure from the depth without reference to the concrete; but the actual pressure by experiment had never been elicited.

Mr. Smyth—M. Chastelain said the experiment had not been made, but it would be very possible to make it, and when made, to give them the exact result. The practice had been to calculate the thickness and strength of the tubbing from the maximum pressure due to the hydrostatic column, and they had not verified the pressure by actual experiment.

Mr. Marley—Only that might not always give the actual pressure, because, if the sinking is on a plain, and there is a large mountain near, and a feeder had its source in and percolated from the mountain, there would be a greater pressure to contend with than the depth of the shaft would give.

Mr. Smyth—But the water rises to the surface ?

Mr. Marley—Yes, when it rises to the surface, the question is answered, but not otherwise.

Mr. G. B. Forster—Mr. Marley alludes to close-topped tubbing. He knew an instance where a second crib had been laid in below some open-topped tubbing, with a communication through the top cribbing; this opening having got choked up, and the pressure being augmented by a blower, the gas burst the tubbing, which had to be taken out; but he imagined that in Messrs. Kind and Chaudron's method the water could always find its way at the back of the concrete, and the tubbing was, as Mr. Smyth had explained, essentially open-topped.

The President—If their remarks were brought to a close, he must say, it would not be reasonable or fair to ask these gentlemen to attend on a future occasion. He thought the meeting would agree with him, that the number of questions which had been put, and the very unreserved manner in which they had been answered, and the very explanatory way in which the answers had been followed up, had satisfied the requirements of the members. He thought also, that they would agree with him that they should not part on that occasion without passing a vote of thanks to the gentlemen through whose instrumentality a very valuable paper, and a great quantity of very interesting information, had been brought before the North Country coalowners. He accordingly proposed a most cordial vote of thanks, both to Mr. Smyth for writing the paper and introducing the subject, and also to the two gentlemen MM. Javal and Chastelain, who had taken the trouble to come to them that day; this vote, he was glad to see, was unanimously responded to. He begged, therefore, on the part of the Institute, to return these gentlemen their most hearty thanks for their great courtesy in taking the trouble to come and visit the Institute on that occasion.

M. Chastelain thanked them very much on behalf of his friends and himself, and regretted that he could not speak their language sufficiently well to address them.

The PRESIDENT said, the preliminary notice stated that the report of the Committee appointed to classify the Rivetting Experiments would be brought before them that day, but he thought that as the report was mostly a detail of figures, it would be unsatisfactory to read it, and he proposed, therefore, that it be printed and circulated along with the rest of their papers.

ON THE EDUCATION OF THE MINING ENGINEER.*

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To commence an address to such an association as now honours the writer by listening, with the definition of a mining engineer, may be to secure that precise understanding which logicians insist on; but to most it will seem a work of supererogation. Yet it may be questioned if, habitually as the phrase is used, there are any here who have ever asked themselves, what are the limits of the duties of the mining engineer? And the writer does not question, he is certain, that not one has endeavoured to ascertain how any one assuming the title has qualified himself to do so. He speaks thus confidently, because it seems to him a matter of certainty that, had British engineers ever fairly faced the inquiry into the rights of men to assume the name of "engineer," some measures would have been taken to protect the title—not by trying to limit the number of holders, but by granting it to as many as proved themselves qualified for the responsible duties of the profession. But of this again.

A mining engineer is one to whom is credited sufficient knowledge of the conditions under which minerals occur in the earth to render him a reliable adviser in the search after them; who is believed to know the qualities of minerals so as to decide on the worth of any that may be found, and who, these points having been satisfactorily decided, possesses sufficient mechanical skill to conduct all the operations connected with

* This paper was prepared for the Meeting of the North of England Institute of Mining and Mechanical Engineers and Institution of Engineers and Shipbuilders in Scotland, held in Glasgow in August, 1870. The large number of practical papers to be discussed necessitated its postponement.

the extraction of the mineral from the earth. He who merits the comprehensive title of mining engineer should be a geologist and mineralogist as well as a civil engineer. In this sense—and it is the only rational one—there are *very* few mining engineers in Scotland. This is no reflection on the existing representatives of the order. It is much to be regretted that there are so few facilities for their position being rectified; but so long as the educational opportunities are so defective—so long as there is no body whose interest it is, or might be made, to insist on a certain amount of instruction—there is no use blinking the fact that mining engineers are unqualified in the sense that our advocates, medical men, and clergy are qualified.

Now, before urging any change, one or two questions have to be answered. Those who are most deeply and directly interested in the efficiency of the mining engineer are the proprietors of mineral wealth. Are they content with things as they are? Do they believe that the men whom they presently employ, on whom they rely, are deserving of that confidence? While admitting that there are many men of superior ability or large experience who are admirably successful in the majority of their operations, there is no question that as a whole the mineral resources of this country are not administered with that economy so important in dealing with supplies, which by their very nature are terminable, whose exhaustion is a certainty, though the date may be open to controversy. The evidence in support of my statement it is difficult to give. It is to be found in the censures incidently dropped by inspectors of mines, and by the better informed iron-masters. But few whom the writer now addresses are ignorant of examples, whose number, considering their limited experience, suggests the frequency with which gross blunders are perpetrated. Many cases could be cited which might be amusing did they not tell of disappointed hopes and loss, even ruin, to those who put their faith in the so-called practical men. But, referring to a few which stop short of the tragic, it is well known, that bores have been sunk from one side to the other of faults, whose existence was revealed in adjacent but unvisited brooks, the bore being put down at great cost into beds far below the valuable stratum sought for. An eminent engineer has counselled the lease and working of a property which contained beds lying immediately above the coals sought for, in ignorance of the fact that there was an extensive overlap or unconformity by which the productive seams were thrown out, and the property, therefore, valueless. As a converse, some years ago an engineer, having seen the results of borings, accepted these as evidence, and counselled his client to his ruin, it never having occurred to him to test the authenticity of the specimens submitted, or to compare them with the geological facts revealed by sections in the vicinity. But why multiply what are in reality bits of gossip, in so far as they deal only with particular cases? The existence of the "mystery-men," the borers, as a class, is itself evidence of a defect somewhere. These men should be the servants of an instructed engineer. In reality they are masters by virtue not merely of their mechanical dexterity, but of the tradition of their local knowledge. Great as are the writer's obligations to some members of this class, truth compels him to add that the boring machine exhibited at your congress in August—a machine which withdrew a cylinder of rock—was to his mind a powerful educational engine, since it would certainly curtail the supremacy of the borer and impose more direct responsibility on the engineer. The notorious frauds of unworthy members of the one class would be prevented, and the ignorance of the other class would be deprived of the protection from responsibility, which the opinion of pseudo-experts has hitherto afforded them. It is insisted that men who have given their lives to one district are more likely to know that district better than a stranger, an argument which would prove a mole a good geographer, because eminently careful in local research—an argument which, to be valid, requires proof that the local worker has something more than mere rule-of-thumb knowledge. It is a curious commentary on this doctrine that the most strenuous advocate of the superiority of local men, is the wealthy employer who trusts his capital to a manager of life-long experience, but of such slender knowledge that he thought hæmatite contained 90 per cent. of iron! It is not the M'Clarty philosophy of doing well enough which ought to suffice. It is the best possible which ought to be secured; and though this may involve a little pecuniary sacrifice, it is not the less a duty to our successors to act, not as the life-tenant of an entailed estate who has quarrelled with his successor and spoils it as far as may be, but to act as the conscientious trustee who shall hand over his trust benefited as far as may be. Nor is the sacrifice of money likely to be so great. Properly administered, skilled labour is the cheapest. Selfishness requires for present benefit a line of conduct, which shall at the same time fulfil the higher moral obligations just alluded to.

Motives of personal interest, therefore, seem to justify the insistence by mineral proprietors on some organised scheme for the instruction of the men on whose advice they rely.

But the profession of engineers has a duty in the matter. At present any man can call himself an engineer, and a mining engineer may be defined in practice as a man whom chance has brought into frequent contact with mineral proprietors. Reverting to what the writer has already said concerning the functions of a mining engineer, he appeals without hesitation to this audience for an emphatic declaration that such a state of things should not exist. Your reputation as a profession is at stake. Your relations to the public are not defined. Is it wise to leave the public in absolute uncertainty as to the character and qualifications of those whom they wish to employ? If it is contemplated to procure a charter for your Institution, that charter ought to include a class of men whose special knowledge is worthless, even if they possess it, unless it is combined with the thorough equipment of the civil engineer. But apart from the injury to your own profession wrought by the unchecked multiplication of tradesmen, who assume the same style as the accomplished scientific men among your number, your voluntary association imposes on you a duty which is of paramount importance. It is inept to say that the public will soon recognise the difference between the good and the bad. It is not even true; for we know that many quacks retain a position forfeited by their ignorance and blunders, but secured by their impudence. And even if it were true, is it right? Every such experiment made by the public involves loss. To throw on the public the duty of thus testing professional men, is to tax them very heavily, as if people were to select their medical men by trial, that trial involving many deaths.

It is for the profession to consider the amount of its obligations, to determine whether it is to consist of so many units, each competing with his neighbours and anticipating his fate by the uncertain operations of the law of natural selection; or is to form itself into an instructed court qualified and courageous enough to decide who are or are not entitled to public confidence.

Assuming it as admitted that intuition alone does not fit a man for the duties of a mining engineer, and that merely local experience does not place him above the level of an underground viewer, what training is best fitted to impart the necessary knowledge in the shortest time? It is further necessary to assume that the Institution of Engineers recognises a duty as well as expediency in procuring, if it does not already possess, powers to certify the qualified in this particular branch of the profession. Only three courses are open:—1st, to certify upon examination any one who desires to be tested; 2nd, to impose certain conditions as regards study upon all who seek examination; 3rd, to establish a school or college, or to obtain paramount influence in some such establishment already existing, in which the necessary training preliminary to examination may be obtained.

Discussing this last mode of meeting the difficulty, it would seem to be a cause of satisfaction that at present there is no prospect of any such attempt being made. Any new school could only, as things now stand, injure existing schools or colleges without securing its own end. There is not money to be had sufficient to start a scheme which would not injure them. It would require £3000 a year as a modest minimum to secure the teaching of the higher branches, and where is the preliminary training to be got? Either by opening preliminary schools, or by insisting on an entrance examination, which would for some years keep the college empty, till the schools responded to the stimulus, and that would only be if the engineers counterbalanced in profit the payment by results which at present holds the schoolmaster's nose to the department grindstone. Obviously the scheme would be too extensive both in scale and cost. But there is hope the day may come when it may be realised. There are many subjects not yet included in the university curriculum which are nevertheless capable of theoretical discussion, as mining, metallurgy. The time will come when these shall be included. Thereafter the co-operation of several professions and trades will render possible the formation of what, for lack of a better phrase, may be called a technical school, one, that is to say, in which instruction will be given, not in theory, but in the application of theory to practice. Thus, practical chemistry, geological field-work—in other words, the art of mapping a country—will find a place, not as superseding, but completing the higher instruction. To the practical laboratories would come those engaged in textile manufactures as well as engineers. But this is looking farther forward, perhaps, than many here may think advisable. The writer would revert, therefore, to the first of the plans proposed—that of a professional examining board granting certificates, on examination, to all who choose to come before it.

Theoretically there is no objection to the existence of such a board independent of a university. In fact, in the case of the medical profession, the writer has recently urged its creation by Government, on the ground that a perfectly impartial and independent court of examination in practical subjects would give a security not to be obtained under our present system. A similar court controlling the admission of engineers to the profession would be a most desirable innovation. Of course, the co-operation of members of the profession throughout the country would be necessary, but that co-operation does not seem difficult to obtain. The Institution of Civil Engineers in London has a body of laws, which has secured such general approbation, that the regulations of local institutions are only suitably modified copies. Our friends from the North of England, and those in the West of England, represent considerable areas and large interests, while the mode in which they have testified their sympathy and goodwill is an assurance that their aid will not be hard to obtain in furthering any scheme having the general good in view. Nor is there any difficulty in procuring examiners. The profession contains very many who are well qualified to judge on the knowledge and skill of candidates, and such men, of high attainments, are sufficiently distributed through the country to give good prospect of that uniformity of standard, so needful when the same honour is to be awarded in all districts. The association with the court of teachers—be they professors or other—is a detail only to be settled after the subjects have determined in which candidates are to be tried. But in no case should any assessor be elected save on the ground of demonstrated practical skill in addition to theoretical attainments. Supposing the court agreed on, then, on what conditions may candidates present themselves? They must be men who have either gone through an organised course of study, or who have prepared themselves for examination, when, where, and how, it seemed best to themselves. The latter is free trade in education, of which the writer has elsewhere avowed his theoretical approval, though in practice it ought to be condemned as concealing a mischievous fallacy. In one or two subjects it is possible a student may learn thoroughly by his own efforts, but in the majority, more especially when equal knowledge of all is needed, such private study must fail, save after an expenditure of time, which would in effect make the profession the monopoly of the wealthy. The system of apprenticeship will of course be appealed to; it is a very important educational agent or method, but in objecting to the extreme value, which many are disposed to attach to it, there is precedent in the medical profession. It is a useful auxiliary of, it is an admirable sequel to, connected systematic study. But because it is of necessity unsystematic, it cannot be held as superseding organised courses of instruction. Time was when to have sat at the feet of some Gamaliel, of itself conferred distinction and inspired confidence, but that time passed away as science became more extensive and precise; it was an admirable way of acquiring practice, but it is not the way to learn principles. The retention of the apprenticeship system is indispensable, but its place in the scheme of study requires still to be fixed.

In thus objecting to free trade, it remains for the writer to state the course of study which the imagined court should impose. Several universities have laid down curricula for the civil engineer and confer certificates or degrees on their satisfactory completion. Having recently become a member of the engineering department in Glasgow University, it may be permissible here to refer to Professor Rankine's efforts, and to congratulate him on the public recognition which has to some extent rewarded, and which, it is hoped, will still more emphatically reward his exertions. Let it not be supposed that any interference is suggested with that or other schemes. On the contrary, it is in the power of the Professor to aid in giving them still more importance by making the degree or certificate a prerequisite to examination for admission into the chartered body. It would follow, of necessity, that the court would not go over the ground covered by the universities or colleges presently in operation. Their work would be the application of tests, which would show incidentally the possession of ample theoretical knowledge, but which would have as their primary object to prove the possession of practical skill, the power to apply theory to actual work. This, however, deals more with the civil engineer, as the term is commonly understood. For the mining engineer no such course is as yet prescribed. The conduct of Sweden and of France in this matter might be referred to as justifying an insistence on some addition being made to the ordinary engineering course; but it will be sufficient to speak of the mining school in Jermyn Street, the only one which has survived in this country. It is now two years since this question was discussed in the "Daily Mail," and the description there published may be quoted:—

"Thirty-six years ago Sir (then Mr.) Henry De la Beche began the geological survey of England as a private enterprise. After some years of labour the recognition of Government was secured for the undertaking, and was richly earned by the success with which the survey had been conducted, and the promise of important economic results which its extension held out. In 1851 the building in Jermyn Street was completed by Sir R. Peel's Government, and became an educational establishment of the highest importance to the miner and metallurgist at home and in the colonies. The building contains the offices of the Geological Survey and of the Keeper of Mining Records; the Museum of Survey, mineralogical and metallurgical specimens; and the classrooms and laboratories of the teachers, except the chemical laboratory, which is in a separate building, the Royal College of Chemistry, Oxford Street. All these departments are under the control of Sir R. I. Murchison, but interesting as are their history and organization, it is proposed to confine attention for the present to the Royal School of Mines.

"The staff of the school consists of the Director, Sir R. I. Murchison; and the Lecturers—On Chemistry, E. Frankland; Natural History, T. H. Huxley; Physics, Guthrie; Applied Mechanics, R. Willis, M.A.; Metallurgy, J. Percy, M.D.; Mining and Mineralogy, Warington W. Smyth, M.A.; Geology, A. C. Ramsay; Mechanical Drawing, J. H. Edgar, M.A. The curriculum is as follows:—

FIRST YEAR.—For all Divisions.

1st Term, Oct.—Feb.	2nd Term, Feb.—June.
Inorganic Chemistry with Laboratory Practice.	Physics.
Mechanical Drawing.	Laboratory Practice.

SECOND YEAR.—For all Divisions.

Mineralogy.	Geology.
Mechanical Drawing.	

THIRD YEAR.—A. Mining Division.

Mining.	Applied Mechanics.
Assaying.	

B. Metallurgical Division.

Metallurgy with Laboratory Practice.	Applied Mechanics.
	Metallurgical Practice.

C. Geological Division.

Natural History and Palæontology.	Palæontological Demonstrations.

"The studies of the first two years are compulsory on the candidates for the associateship, but 'in the third year the candidate may confine himself to the Mining, Metallurgical, or Geological Divisions, and pass his examination in the first class of one of these divisions only.' Whatever division, therefore, a student may select with a view to his future career, his proficiency in that division is based on a sound knowledge of those subjects without which the practical miner, metallurgist, and geologist may, indeed, be a good tradesman, but cannot be a man of science. The fee for students desirous of becoming associates is £30 on entrance, or two annual payments of £20, but this admits only to the lectures; the fees of the Metallurgical Laboratory are £15 per term of three months; for the Chemical Laboratory, £12 for the same period.

"Certain endowments are connected with the school, namely, three sets of prizes, and fifteen bursaries from £15 to £50 each, the latter (three in number) tenable for three years. Few schools are so richly endowed; in few have the highest honours been so sparingly given, the number of associates admitted during seventeen years being only 42. An increase is noticeable in the number of candidates—nine obtained the honour in the first five years, 10 in the second, 17 in the third, and six have been added during the last two years. Their certificates are in the following divisions :—

Mining, Metallurgy, Geology	12
Metallurgy, Geology	8
Mining, Metallurgy	4
Mining, Geology	3
Geology	10
Metallurgy	3
Mining	2

"It is worthy of remark that the majority of the 12 certificates in all these divisions were given in the first five years, and all were prior to 1862. As might be expected, the greatest eminence has been subsequently reached by the first, the most numerous group of proficients in all these divisions. This school was originated, and has succeeded, in spite of the fact that no mining or metallurgical operations are conducted nearer London than Bristol or Gloucester, and that no district within this minimum distance offers opportunities for practical instruction at all to be compared with those, which are to be found in the immediate vicinity of Glasgow. It was founded in answer to an appeal made by the leading representatives of the mining interests of Great Britain. But it does not appear that Scotland has as yet benefited largely by the Jermyn Street teaching. It is difficult to give a reason for the absence in Scotland of anything approaching to a mining school. Our mineral properties are, on the whole, as well managed as those of England; in metallurgy neither pains nor cost have been spared in procuring the best advice and practising the best methods. Yet nowhere can any one, proprietor, manager, or miner, obtain any information as to his work, save by apprenticeship."

This was written in support of a scheme for the institution of a lectureship on mining. At that time the writer's efforts failed, and his expenditure for two sessions in providing a competent lecturer was thrown away, save in so far as his sincerity in the matter was subjected to the severest test of loss of money. Failure has not, however, diminished his hopes. He is sanguine enough to anticipate the erection of geology into a separate chair as well as the foundation of the mining lectureship.

From the passage just quoted it is evident that in Glasgow University (to take the nearest example) all these subjects are taught save mining, assaying, and metallurgy. The chemical laboratory might do something were good cause shown in the way of assaying; instruction in mining it would not be difficult to procure, but metallurgy is beyond hope for some time at least, the cost of the laboratory being the chief obstacle. For the present, therefore, the court, such as has already been indicated, would have no power to prescribe that full complement of study open to the student in Jermyn Street. But it would be in the meanwhile competent to require proof of skill as acquired during apprenticeship to, or pupilage with, a professed mining engineer. This would not accomplish all the desirable good, but it would be a step in the right direction, and those who wished and who could afford it might repair to Jermyn Street for what they could not get here.

To the appeal for means to establish a mining lectureship the frequent answer was, that those at present employed are good enough without further instruction. When the possibility of skilled men introducing new methods was suggested, something like a devout prayer was breathed that such a possibility might never be realised. It happened that the lessons which had taught this wholesome fear of forsaking the customs of their forefathers had been taught not by skilled men, but essentially by unskilled men. In the West of England at present there is at least one striking example of which many of you are probably aware, where a highly trained pupil of Jermyn Street has, amid derision and sympathetic hope for his ruin on the part of those who have been all their lives working in the district, followed his own way and realised a fortune, because, as a geologist, he knew that a hill capped with trap was not a hill of trap, though several largely employed engineers and experienced managers were prepared to swear to the contrary.

It is perhaps a better key to the writer's failure that the proposal was made with a view to the connection of the lectureship with a university. University training, it was more than once said, did not make men more fit for business, rather the reverse—a courageous statement, since at the time the sons of those who said so were attending university classes. But as an example of what scientific training may do, let the writer refer to the work of Mr. Hull, now the Director of the Geological Survey in Ireland. When engaged in the survey of an important English coal-field, evidence was lost at one point as to the lie of the seams. Trusting to the information yielded by the other strata, he mapped the country, indicating conjecturally the position of the coal seam, showing, that is to say, where it would have been had its course been normal. He further prepared, as was customary, a section of the country, and gave the depths from the surface at which, barring subterranean contingencies, the coal would be. Acting on these statements, a proprietor sank at two miles from the last proved point and found the coal a fathom nearer the surface than Mr. Hull with commendable prudence had said. It may be questioned if all the mining engineers and managers put together would do as much here. And no discredit to them; they have never been taught the art of field-mapping, the application of geological science.

The profession of engineers is here appealed to, to step in and protect their own profession. If the time has not yet come for them to acquire the organisation which has done so much for medicine and law, it is at least in the power of individual members to enjoin on their pupils and the younger members the duty of paying some attention to those matters, on which they may be called upon hereafter to give responsible opinions.

In this direction much good might be done by the intervention of such an institution as this, in behalf of the introduction into schools of such teaching as would assimilate some of them to the higher primary schools of France. Mere chemistry, physics, and geology might be got in at the cost of fruitless time spent on subjects profitless in themselves, or because of total inaptitude for them on the part of the learner. Not only might the time of the student be thereby economised, his stay at college being proportionally curtailed, but science would be benefited, because the university teacher would be spared the drudgery of elementary instruction, and enabled to apply his thoughts to the cultivation of the higher branches of his sciences.

But the purpose of this paper has been to insist more particularly on the fact, that the engineers of this country have attained a numerical strength and a position, both socially and in science, which justifies them in securing privileges similar to those now held by other professions. And the first use to which the possession of those privileges might be advantageously turned, is the assertion of the right to declare on what conditions membership may be obtained. The control of professional education is one of the first duties, were it for no other reason than to stop the curious absurdity of its being legitimate for any man to put C.E after his name, allowing the ignorant to believe him qualified, and to learn the truth only after they have been ruined. Many members of your institution can relate amusing results of this extraordinary procedure, without parallel in any other profession, requiring for its exercise equally great scientific attainments. But the writer is not competent to judge of civil engineers. Of mining engineers he has had opportunities of knowing something, and in the strength of that knowledge he urges the attempt to provide better educational opportunities for them than now exist, and the duty of insisting that the title be assumed on some better ground than accident or caprice.

The court of examiners, whose position and powers could only be secured by Act of Parliament, would find its highest reward in confining its attention to the practical testing of candidates, leaving the schools and colleges unfettered as to the conditions on which they may grant their certificate or diplomas. Free competition between the schools would soon secure a high standard of teaching; and especially if the results of their work were to be reviewed by an independent court of examiners. But to secure this benefit the certificate of a school should be required of every candidate. The certificate of the court of examiners would be, in fact, a license to practice. But it may be hoped that the granting of this license would not close the relation of the examinee to the institution. The licentiates of the medical colleges have neither part nor lot in those bodies, unless they afterwards, at much cost, become fellows. Profiting by their experience, a new corporation would do well to consider whether the examination fee might not be such as to confer membership—actual membership, not a titular relation. So might the institution become, not a voluntary society, but a brotherhood of common aims, and exercising a mutual influence for good.

Such are the views which the writer has taken the liberty of bringing before you. For the dogmatic character of several of these statements he would crave pardon, but that his remarks may thereby provoke more unsparing criticism. Such criticism is, to him, an object of much importance, because his views are common to many members of the profession; and among his medical brethren the similar views he has elsewhere expressed, regarding medicine, meet with some sympathy. To impose on independent bodies the task of proving the practical skill of students, thereby to relieve the schools of responsibility in all, save the provision of thorough education, and to aid the teachers in discovering the best mode and kind of instruction, these are the aims which many members have set before themselves, and which, before many years, they will see accomplished. But if their hopes are to be realised, it is necessary that changes may be made with all possible care and deliberation. In advocating change, the writer has unbounded faith in that conservatism which is inherent in all large bodies of men, which protects against rash meddling, and gives security that nothing will be done which has not been proved to be good.

In the after discussion,

Mr. Ralph Moore said, that the Professor based his lecture principally upon the fact, that because some mining engineers were ignorant as to the geological position of certain objects, therefore, they should have a mining college, or some similar institution, to instruct them in the science of geology. There could be no doubt it was desirable in mining, as in every other branch of engineering, that those engaged in it should be well qualified by education; but it must be remembered that local knowledge was of paramount importance in mining. A mining engineer bred in Glasgow would be of very little use in Cornwall, as the one is devoted to mining in the coal measures of Lanarkshire, whereas the other is employed on the mineral veins of Cornwall. But geology was not the only information required: the mining engineer, besides having a local knowledge of the measures with which he was connected, required the practical knowledge to know how to work them. Regarding the imperfect geological knowledge of the Scotch mining engineer, he might as easily retort upon the Professor, that in Edinburgh, the seat of learning, where very many had written upon coal, it was only within the last ten years that the position of valuable ironstone had been classified, not by any learned philosopher, but simply by comparison of the fields by those having local knowledge. No doubt they would be all better of more education in the profession; but of the 42 students sent out by the Mining College in Jermyn Street, he would like to know how many of them had been practically employed in mining, and what was the practical result of their training.

Mr. J. M. Gale said, he thought Dr. Young's remarks applied to all branches of engineering as well as to mining. He held in his hand a pamphlet which had been published by the Institution of Civil Engineers in London, in which is given a vidimus of the various educational institutions in Europe, where instruction is given bearing on the profession of engineering. Among other things, it contains the suggestions on the subject of the future education of the engineers of this country, by Professor Jenkins of Edinburgh, of Mr. Scott Russell, Mr. Henry Conybeare, by some of the most eminent engineers of the country, by Sir John Rennie, by Mr. Calcott Reilly, and others. There could be no question that taking a youth from our provincial schools, or even from the schools of some of our larger towns, into the office of a civil, mechanical, or mining engineer, much had to be learned besides practice. He may pick up a good store of knowledge, he may see plenty of work going on, but after passing through a five years' pupilage in ordinary circumstances, he is very unfit to practice either as a mining, mechanical, or civil engineer. He spoke from his own experience, and he believed he spoke the experience of every engineer. It had been proposed that they should adopt the system prevailing on the Continent, the fullest development of which might be seen in France, where mining engineers took precedence of civil engineers. The profession on the Continent was on a very different basis from this country. All engineers there, or at least the greater number, were Government officials. They were educated under the Government, their promotion was watched and regulated by Government, and they were pensioned off in old age by the Government. Those who were smart men got on faster than others. Here was a vidimus of their education in Holland. There was five years' tuition. The youth was supposed to begin at the age of 18, which made him three-and-twenty when finished. He had to study mathematics, mechanics, natural sciences, chemistry, zoology, and botany, geology and mineralogy, cosmography, Dutch laws and constitution, political economy, geography, history, commercial science, Dutch language and literature, French language and literature, English language and literature, German language and literature, caligraphy, ordinary and rectilinear drawing, gymnastics and drilling, practical chemistry in laboratory, and experimental philosophy. The student had, in going over the course, to devote, during the first and second years, 37 hours a week in the class room; during the third and fourth years, 38 hours per week; and during his fifth year, 39 hours a week. He was then 23 years of age.

Mr. R. Bruce Bell—He is not bound to be perfect in all these?

Mr. Gale—He must go through a certain number of examinations on these subjects to qualify him for certain departments, for those separate departments did not give the qualification. The examinations were very severe, and what it all came to was this—that there were 900 picked youths, of 18 and 19 years of age, each straining every nerve to win one of 150 appointments annually made for admission to the Polytechnic School, in France. But these 150 were far from having reached the practical part of their profession. For two years the 150 had to struggle for 25 posts, and the 125 who failed, after going through all the higher classes of mathematics, theoretical mechanics, mathematical physics, curious problems in descriptive geometry, etc., have to degenerate so far as to look after State factories for powder, tobacco, or saltpetre. Now, it was all very well to give youth a good education, but what was the use of five years' tuition like what he had described? He believed the immense crowds of people who sought these situations on the Continent did so because the school was under the Government support, and paid by the Government. There was no fee required for entrance, and he believed if there were it would check the great numbers who entered those schools. Now, something was required to be done in this country; but he did not think it should be done by the Government, but rather by private enterprise. Those private establishments have been greatly on the increase in this country; and one had started at Manchester recently. Engineering was also taught at Edinburgh University, and in Glasgow University. He was sorry to say that, although in Glasgow there should be three or four times the number of students that there were in Edinburgh, yet the learned Professor of Engineering here was not receiving one-third of what the Edinburgh Professor was getting. He thought that the Glasgow University Engineering chair should be better supported, more especially when it is filled by a Professor who is an ornament to the profession, and whose works are known and valued wherever engineering is known and studied. He was very sorry, indeed, to hear that there was a proposal to take from the present Professor a portion of what he received from the students—to divide the students, or to establish another class similar to the class that was taught by Dr. Rankine in Glasgow. He was of opinion that anything more cruel could not be proposed with regard to one who had the interest of engineering at heart. There was a proposition connected with this institution, which had for its purpose the teaching of an under class of men, such as foremen, the better to discharge their duties: what they wanted was to teach artizans who might become foremen, or something above the ordinary labourer—to educate them in some measure to fill the gap between learned professors and the common workman. In this country there were professors of engineering, and means in the universities, where men who had the money to follow out the professional part of civil engineering or mining engineering could do so to the utmost advantage. There were workshops where the best practice in any country in the world was to be obtained; but they failed to catch the middle men—they had no means to instruct them so that they might be usefully employed as practical mechanics in their workshops.

Mr. R. Bruce Bell said, he thought there was much in what Dr. Young had said worthy of discussion, and that the discussion might be adjourned very advantageously. He thought that some of the members had taken rather too warmly the pointed remarks of Dr. Young, as it appeared to him that the learned Professor did not so much mean to attack the present race of engineers, as to point out what should be done for the better education of the profession; and if the paper were printed and laid before the members, they might have some valuable suggestions upon the subject.

Mr. Day concurred generally in Dr. Young's remarks, but he could not hide from his own views on the subject of "Technical Education," the conviction based on facts, that in every case of education, the ruling characteristics of the nation should be duly weighed before it was decided as to the scheme which should be adopted. It was an opinion widely entertained, that in the British mind there is resident a more inborn insight and ability to cope with the carrying out of mechanical and engineering matters,* than what other European nations possess. Whilst he was one of those who would exert himself to do whatever little he might be able in raising the education of the engineer to a maximum in the acquisition of theoretical knowledge—that is to say, strictly those exact sciences to which all structures and machines must be referred before an estimate can be formed as to excellence or fitness—yet he was further convinced that much had been said in these latter days which tended to show that *the* essential in making an engineer out of a youth was a high mathematical education; now this, really, while *an* essential was only going half-way to bridge the difficulty. It is a fact that the profession in its various branches has too often been filled with men who have been launched into it, stimulated alone by the prospect of large fortunes, which many engineers, more than any other class of professional men, have amassed; hence, the profession includes at the present time many who have ranked high in mathematical and other scientific attainments, but who are sub-engineers by nature—who have not the insight, that gift of nature, by which, independent of all science, our earliest engineers were excellent practical constructors. This led him at once to a point of prime importance, namely, the necessity of devising some test by which the youth's fitness for the profession might be ascertained, before he should be allowed to practise. Whilst the Continental system of educating youth for the profession might suit the national habits of these countries, he should much regret to see any attempt at founding any analogous system for the educating of British engineers, but he quite agreed that some urgent step must be taken to raise the status to a much higher level than that which is "picked up" in the offices of engineers in this country. The difficulties in the way of

* This opinion too is confirmed by a definite statement on the subject in the introduction of the volume on the "Education and Status of Civil Engineers in the United Kingdom and in Foreign Countries," just published by the Institution of Civil Engineers.

youths becoming proficient in the science and practice of engineering in this country at the present time were intolerable, as he, from his own experience while a pupil, could testify.

Professor Young said, he was glad that so much comment had been made on the remarks which, undoubtedly, he had felt some little nervousness in making. He hoped that it might be possible for him to be present at a future meeting; but no one would rejoice more than he would do if everything he had said was called in question. The discussion was the practical part, and he hoped it would be spread over as wide an area as possible; but, if his conclusions were upset, the disproof should be founded on sound reasoning. In reply to his commentator, he might draw a picture from the practice of medicine, of which he had professed no knowledge, respecting which he should like to give some enlightenment. He had a pain in his eye, and he went about searching for a man to relieve him; or he had a pain in his stomach, and he sought for a man with skill in that locality. He need not illustrate that further. A man was incapable of local efficiency unless he had mastered the general principles. The gentleman was not quite correct in his account of the history of the ironstones, for it so happened that the information was not elicited by comparing two fields, but by the comparison of fields in England, Scotland, and Ireland—a comparison at which the mining engineer would have turned up his nose, for it involved fields where scarcely a scrap of iron ore existed; a geologist would have been thoroughly aware of this circumstance. He was indebted to the other two gentlemen who had spoken on the paper. He hoped he had made it understood that the University was not necessarily, nor should it be, what, for want of a better name, he would call a technical school. It was so at present, but he did not say that there were no other good schools; and, therefore, he desired the establishment of an independent board formed from the profession of engineers itself, so that it might be competent to accept the certificate or diploma of any school properly qualified to give instruction. It was to give practical free trade, so that any engineer might go to any school he wished, that he pressed upon them the appointment of independent boards; and it was to prevent what Mr. Gale deprecated, elaborated scientific machines, such as were to be met with on the Continent. He hoped that he had made that point sufficiently clear, and that his remarks might be a centre of some discussion, being convinced that the good he anticipated would be realised before long, and, that at the hands of the profession of engineers themselves. He concluded by expressing his great obligation to the

Institution for giving him an opportunity of addressing them, and expressed the hope that his paper might be very thoroughly and satisfactorily criticised.

The PRESIDENT said there was no branch of engineering that required such a diversified training and practice as that of the mining engineer. Dr. Young stated that he must be a geologist, a mineralogist, and also a mechanical engineer, besides possessing a purely theoretical education, of a very high character; that all these were required if the profession was to be properly represented. The education aimed at by Dr. Young was clearly of a more exalted kind than has been hitherto within the reach of many of our more practical and local engineers, or even what they have been accustomed to consider necessary. A purely theoretical education, of whatever degree, must necessarily be followed by that practical experience which alone can be got from the actual laboratory of nature. In this country a preference has been shown towards the man of large practical experience, while in France, where a higher theoretical education is required, it appears that for 150 places to be supplied, there are 950 applicants. Mr. Day has stated that we are a nation of engineers—the faculty of engineering, however, does not run in the blood—and we have acquired this character not so much from any high-class theoretical education which we may have possessed, but rather from the abundance and extent of our coal and mineral fields, and the large industries connected with mining, affording those engaged in such work the best opportunities for acquiring a thoroughly good and practical knowledge of the requirements for conducting such operations. While agreeing with what Dr. Young aims at in reference to mining engineers, the practical fact stares us in the face that the great bulk of the people in this country are unable, from circumstances which they cannot control, to attain to that high position in theoretical education indicated. While we look to our universities to supply the education sought by Dr. Young in his paper, it is desirable not to forget that the most of our people must spend the principal part of their time in the workshop, and it is of importance that a degree of education, though not so exalted, should fall to them, for out of this thoroughly practical class come our ablest managers, leading men, and foremen.

December 9, 1870.—*Note by Mr. Ralph Moore.*—He thinks it would not tend to improve coal mining to enforce the high standard which

Dr. Young contemplates. Also that the reason why the student of Jermyn Street School of Mines, and of the foreign Schools of Mines, fails to get a position in coal mining here, is, that too much of his time is spent at school, and too little at the mines learning that particular branch of the science of mining which is meant to be followed out. Thinks a *moderate* educational test might be advantageous. Take, for example, coal mining. Believes that it would tend greatly to improvement in coal mining, if quarterly examinations of collieries were made by properly qualified neutral mining engineers—at the joint expense of landlord and tenant.

These quarterly examinations should include the whole arrangements and machinery at the surface of every pit; the whole arrangements underground; and in particular the engineer making the investigation should go through every road in the pit, into every working place, and through all the airways; he should record his observations in a book, on the mode of working, any deviation from it; the mode of supporting the roof; mode of haulage; the minimum height of roads; extent of minimum height; the quality of the ventilation; size and length of airways; the quantity of air in circulation; with any other remarks and suggestions for improvements and alterations on the operations or discipline of the pit, these observations to be recorded in the book to be kept at the colliery for the purpose.

Every mining engineer, before being appointed to make those examinations, should be able to show to a board of examiners that he is fully qualified, and a fair test of his qualifications would be that he—

Has been two years in a civil engineer's or mine surveyor's office, and able to survey mines, and construct branch railways, and other erections at collieries.

Has mechanical drawing, plan drawing, and freehand sketching. Has been two years at a colliery, engaged in the office, but underground for ten hours each week during that time.

Has a knowledge of the different modes of working and ventilating coal; of haulage; of sinking; and of mechanical engineering, as applied to collieries.

Has a knowledge of the theory of steam and mechanics, and some knowledge of geology, mineralogy, and chemistry.

The board of examiners might be composed of persons qualified to test the applicant's knowledge of the above. They would require to be appointed and paid by the owners and tenants, who would appoint a committee of themselves for the purpose of selecting them. There might be a board for each of the twelve districts of inspection, and each board could sit quarterly.

Examinations of the mines, such as is here pointed out, would bring before the owners and lessees of minerals, the state of matters as seen by a neutral qualified person, and would doubtless tend to extend the knowledge of, and develop the best systems of working and economizing coal, and would also improve mining appliances and discipline.

It is also suggested that the expenses of such a scheme should be borne equally by the landlord and tenant, because both are interested, and both would be benefited.

Moreover, legislative enactments for mines have hitherto borne solely on the tenants, which is scarcely fair.

DISCUSSION CONCLUDED, JANUARY 17, 1871.

Mr. R. Bruce Bell stated that the paper which Dr. Young read at the last meeting, although professedly dealing with the Education of the Mining Engineer, embraced in its scope the education of the entire profession; and not only the education, but also the subject of graduating and licensing the engineer to practice his profession. These are subjects well deserving great consideration here; but, although such papers, and the discussions to which they lead, may do good in keeping us alive to the necessity of progress and improvement, it would be entirely out of the question, even if it were in the power of such an institution as this, to take the stand proposed by Professor Young. With respect to mining engineering, and the statement which Dr. Young makes as to the position in which the profession stands, he (Mr. Bell) leaves those members of the institution who have made this branch of engineering their specialty to answer, and passes to the general subject of educational qualification and licensing an engineer to practice his profession. In dealing with the last of these, although the Professor's proposals bear more particularly upon the special branch of mining engineering, yet by his paper he proposes some similar course in dealing with the whole body of civil engineers, and he advises that this institution should acquire powers to certify the qualified, and describes the manner in which this should be done. Now, admitting the truth of much of what the Professor states as to the want of a legal barrier to prevent parties entering the profession who have neither the necessary training nor education, and who may entirely want any of the qualifications requisite to entitle them to practice; yet, the proposal, to make this institution the judges of these qualifications and give diplomas, could not be entertained. Dr. Young must entirely misapprehend the nature of the constitution of this institution when he proposes that it should take such functions upon itself. It has been established for a very different object, and is much too general in its character to admit of this. Such a power could only be exercised, as regards civil engineering, by a specially chartered body of civil engineers, similar to that already in existence in London, viz.:—The Institution of Civil Engineers, which pertains to the whole nation; and in mining engineering, the nearest approximation to a similar body exists in the North of England Mining Institute; but it is to be feared there as here, that this latter body is much too general in the character of its constitution to be entrusted with such powers. As regards the civil engineer, he was afraid that for the present nothing could be done in the way of special licensing, at any rate until some more definite combination of education and apprenticeship or pupilage is adopted than that which exists at present. Nevertheless, he could quite appreciate the Professor's remarks as to the opening that is afforded to ignorance and presumption; but the difficulty is to know, as regards civil engineering, what test could be employed, the passing of which would authorise a Board to admit or exclude a candidate. The mere passing a scholastic examination, although ever so abstruse, would be totally futile without other qualifications of a very different order, which no oral or written examination could eliminate. As well might you pass an artist into the Royal Academy of Painting by the test of a paper or examination upon Art; he must show by his works what he has done and what he can do, and so should the engineer. It may be said, how is a man ever to get employment so as to execute a first work, if he is only to be chosen by what he has done? The answer is simply this—the ranks of the practising engineers should be recruited from the resident and assistant engineers, who, after completing their education and apprenticeship, or pupilage, have been set in charge of works under their masters, and the successful completion of such works is the warrant of qualification which should get them direct employment in similar works; they thus make their first start, and their works then speak for themselves. He did not mean by this to ignore the necessity of a thorough scholastic education, but, on the contrary, would have it a condition that the engineer should be well educated in all the sciences necessary for his profession; but the question of a Board to test and license engineers to practice, on the result of an examination, is another affair, and too difficult a question to be settled off hand. In connection with what the Professor said as to the defence of the public from unqualified persons practising, and as to the danger to the public in leaving it open to any one to call himself an engineer; what must we think of the public constituting themselves the judges of the qualifications of an engineer, as is often now done, by parties in charge of such works as docks and harbours, inviting a competition of plans, and choosing as their engineer the man who can furnish them with the best looking picture, without any guarantee whatever as to his qualifications, and thus probably choosing a man who may have no other qualification than being a good draughtsman, and who may not even have this qualification, it being left perfectly open to him to employ others to make out his plan for him? He thought in such cases the engineer required to be protected from the public, not the public from the engineer, or rather both the public and the engineer should be protected from men who can take upon themselves responsibilities, for which they are neither fitted by their education nor avocations. Putting aside the question of licensing, which he could hardly see the way to effect, he would speak as to the matter of the education of the young engineer, which is a vital question, and is one which can and should be thoroughly considered and acted upon, but which is, as yet, by no means a settled question. His view of the matter was this:—In the first place, the boy should have a good English and classical education, as far as this can be effected up to the age of 15 or 16, and he should be well grounded in English composition, so as to be able to express himself in plain and proper language, and be thoroughly grounded in arithmetic and the elements of mathematics, in algebra, practical geometry, mechanics, and free-hand and architectural drawing; and he should also have acquired some knowledge of modern languages, passing, if possible, some months in a foreign country. He should then serve a short apprenticeship, say of two years, in practical engineering or house-building, working with his hands and keeping to the workman's hours, keeping up his education in his evening hours. He should then, say at the age of 17, study two years at college, and acquire a general knowledge of chemistry, mineralogy, geology, mathematics, and engineering, and then be articled for four years with a civil engineer in practice, keeping up during that time his college education; at the end of this period, if he has the brains necessary to take in what he has been learning, he should be qualified to design and take charge of works.

Professor Young—Amid the numerous and conflicting statements as regards matters of detail which this discussion has elicited, no one has taken notice of what seems to the author the most important point in his paper, namely, the suggestion to regulate admission into the profession by an examination conducted before a board composed of practitioners. The formation of a faculty has been suggested by Mr. Heppel, as he learns from the Report on the Education and Status of Civil Engineers, to which reference was made at last meeting. But whereas Mr. Heppel thinks of a faculty in each university, he (Professor Young) contemplated a board apart from the university—one which represented the whole profession. Use and wont seems to have given a stronger sanction than usual to a bad practice; for no one seems to have thought it worthy of attention that a professional title is assumed by any one who pleases. Mr. Lyall, indeed, stumbles over this difficulty, but evades it by saying that he "apprehends the greatest, and certainly the most indisputable, right that a man can have for assuming any title in a profession, is the successful carrying out of any part of that he professes." What Mr. Lyall intended to say was probably that success in engineering work entitled a man to be called an engineer. Mr. Lyall may detect the fallacy of this by comparing it with the results that would follow if the same tests were applied to the lawyer or medical man. All the speakers have indicated a strong disposition to regard the mining engineer as a member of the body of civil engineers, and it is sincerely to be hoped that the day may be far distant when the branches of the same great profession shall be separated. The more intimate the relation of the different branches is held to be, the more certain is it that ere long important educational changes will be made. The cost and time involved have been adverted to as objections, and they are well worthy of attention if it could be established that more thorough theoretical instruction, *with the same amount* of practical instruction as at present, would so add to the cost as to injure the profession numerically. But no one has attempted to prove anything of the kind, nor has any one attempted to show reason why the profession should, like the franchise, be brought down to those capable of paying a certain annual sum. Mr. Simpson agrees with the plan for testing, by a competent tribunal, those who "aspire to the position of mining engineer, or of appending that professional designation to their names; but he goes further, and his straightforward statement is very acceptable. He says that the efficiency of an engineer educated up to a high standard would be impaired in proportion to the deficiency of the mine managers, without alluding to that of the miners. It is gratifying to find this spoken by one of the profession, more especially as it accords so closely with the opinions stated at the recent conference of miners. The men are beginning to see that there is something more needed than has sufficed hitherto; let me hope Mr. Simpson will renew the efforts he made some time ago, and will succeed in getting some test applied to the mine managers. The Professor would offer his aid, but that Mr. Simpson says, "though I am not acquainted with Professor Young, or have ever spoken to him, still I may be ranked among his quacks." Surely mere acquaintance with the speaker is not so injurious, and ff Mr. Simpson's sensibilities could be appeased, there is no one with whom he would be more willing to act in common. They both looked at the subject in very nearly the same light; for Mr. Simpson only misunderstood the two cases quoted, and would, no doubt, cordially agree with the remarks of Professor Jenkin on the defects of the English system of education. The case is somewhat different with Mr. Cowan, who says, "Upon the whole I do not see that mine engineering is more dependent on the teachings of science than any other branch of engineering. I admit and agree that scientific knowledge is of the first importance to all classes of engineers, although not more so to mining than to others; and if it be deemed expedient that mining engineers should pass examinations in scientific knowledge, every other engineer should be subjected to the same testing ordeal." Could anything be more handsomely conceded? It almost makes him ashamed to comment on the remarks amid which this excellent paragraph occurs. In truth it must be stated that Mr. Cowan gives two contradictory pictures of the engineer connected with mines. He says that the mining engineer has nothing to do with the how or why of minerals. The sum and substance of mine engineering is the removal of the minerals in the best aud cheapest way. But this is a play on words. It is truly mine engineering, but it is only a part of what the mining engineer is called on to do. Further on Mr. Cowan demonstrates the need of all sorts of knowledge to qualify the mining engineer properly; but as professional chemists, assayers, metallurgists are always to be had, and are frequently consulted, he sees no reason for asking the mining engineer to walk on his own legs as crutches are so abundant. As to geology, Mr. Cowan has not the same idea of that science as is entertained by members of his own profession elsewhere, nor is his language clear. But he admits the important fact—that the mining engineer ought to know something of geology. He thinks that local knowledge is sufficient, as does her Majesty's Inspector of Mines, whom he had imagined to be the representative of the higher culture in the profession. If their views where acted on, Geddes and Landale would find no employment in the West of Scotland, and it would be injudicious, in fact, to consult them, as they want the local opportunities. He has noted one or two points only in these speeches, for the sake of showing that there is no agreement among the speakers, and would remark on one point on which there is agreement, namely, that this institution is not the proper body to act. If the institution endorses this opinion, he must plead guilty to having needlessly occupied its time. But no such censure need be feared. The body has higher aims than to make itself a mere debating club; it realises its responsibilities too thoroughly to stand by and let the profession drift into a wrong position. The Institute in London has taken action, as the report already quoted shows. The institution in Scotland would take action if only some definite course were made clear to it. The discussion which has taken place will do something towards maturing some such scheme, and, therefore, he was gratified at the attention which had been bestowed on the subject of his paper. The admission into the profession by examination would do much towards maintaining the engineer in the dignified position he now holds. It would guard your ranks against invasion by the ignorant and incompetent, who, Professor Jenkin says, enter *because there is no preliminary examination.* This is a different thing from creating a close corporation; but some seem incapable of imagining any intermediate step between the close corporation and that perfect freedom which permits a joiner to start in business when and where he likes. The carrying out of any of the schemes to which reference is made in the London report may take a long time, but in the course of years some organisation will be effected, and it is satisfactory to know that the agitation and discussion will, in the interval, be productive of good. No one would deprecate more strongly than he did any attempt to introduce the foreign system which Mr. Gale so forcibly condemned, nor can anyone be more emphatic in the assertion that neither university nor school can supply the practical instruction needed. What is wanted is so well stated by Professor Jenkin that he will quote his words, with the more pleasure that their substantial agreement was the result of independent thinking.

"It is out of the question that any college training should replace the system of apprenticeship, but it is most desirable that pupils should enter offices better prepared than at present, and that they should continue their theoretical studies during their apprenticeship."

"We do not require special institutions, or any large number of technical chairs, but rather,

"1. Great improvement in secondary schools, especially in teaching arithmetic, geometry, elements of natural philosophy."

"2. The establishment in some large towns, such as Liverpool and Birmingham, of colleges on the Scottish model, or on that of Owen's College—fairly well endowed—giving chiefly general scientific training, with a few special technical chairs."

"3. The practical recognition of the value of scientific training by engineers who take pupils."

> "(*a*). By giving free pupilships or valuable scholarships."
>
> "(*b*). By admitting as pupils only those who have passed certain recognised examinations."
>
> "(*c*). By co-operating with colleges as examiners."
>
> "(*d*). By inserting in agreements with their pupils that during winter they shall attend certain classes."
>
> "(*e*). By giving some privileges, in connection with engineering societies, to graduates."

In withdrawing from this discussion, the speaker again desires to return his sincere thanks to the members of the Institute for the attention they have given him, and to repeat the assurance that his sole object is to help in the onward movement which elsewhere it is sought to impart to the profession. To those who have criticised his remarks, his thanks are also due. From some he differs radically, in assigning to the profession a higher status than they seem disposed to claim; but they will at least do him the justice to believe that his crotchets, as they have been called, do not tend to the lowering of the profession.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, DECEMBER 2, 1871, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

LINDSAY WOOD, Esq., Vice-President of the Institute, in the Chair.

The Secretary read the minutes of the previous meeting and also the minutes of the Council.

The following gentlemen were then elected:—

Members—
Mr. H. D. Furness, Engineer, Whickham.
Mr. H. Chambers, Tinsley Collieries, Sheffield.

Students—
Mr. W. H. Chambers, Thorncliffe Collieries, Sheffield.
Mr. G. B. Walker, North Hetton Collieries, Fence Houses.

Mr. Cochrane wished to take the sense of the meeting as to the desirability of electing the Professors of the College honorary members of the Institute; these gentlemen were all eminent in their respective spheres, and he had no doubt that their contributions to the Transactions and discussions of the Institute would be of great value. He proposed that the necessary formalities should be taken to have them admitted, but he thought in so important a matter nothing should be done without the full sanction of the members.

Mr. Beanlands thought it most desirable that the Professors should be made honorary members, and had great pleasure in seconding the motion.

The motion having been put to the meeting was unanimously agreed to.

The Secretary then read a paper, by Mr. Emerson Bainbridge, "On the Difference between the Statical and Dynamical Pressure of Water Columns in Lifting Sets."

ON THE DIFFERENCE BETWEEN THE STATICAL AND DYNAMICAL PRESSURE OF WATER COLUMNS IN LIFTING SETS.

By EMERSON BAINBRIDGE.

In arranging a plant for pumping water from collieries, the dimensions of the working parts of the pumps adopted are frequently regulated by the sizes of such descriptions of pumps as have been employed without accident to do similar work to that proposed. Where this course is not adopted, the bursting tension is generally assumed to equal from six to ten times the working tension of the pumps, and the dimensions are fixed accordingly. The breakage of the bucket piece of a lifting set, at a colliery under the charge of the Author, led him to make a series of experiments to ascertain the cause of such an accident to pumps which were actually stronger than those usually applied under the same conditions. A record of these experiments is laid before this Institute, with the hope that one or two important points, suggested by their results, may prove useful in pointing out how such casualties may be avoided, and in indicating the safe limit of strength in an arrangement of pumps for raising water by lifting sets.

The paper comprises the following heads:—

1. Description of the conditions under which the breakage took place, with calculations showing the pressure which must have been applied at the bottom of the column.
2. Record of experiments made with a hydraulic gauge, to test the actual pressure at the bottom of the column whilst the water was in motion.
3. Remarks on the bearing of the experiments made upon the general economy of pumping water.

The general particulars of the engine, &c., connected with the lifting set referred to, are as follows:—

ENGINE ...	Diameter of cylinder	84 inches.
	Length of stroke	10 feet.
	Strokes per minute at time of breakage ...	$5\frac{1}{2}$,,
	Do. maximum	8 ,,
	Four valves: condensing both in up and down stroke.	

PUMPS ... At the in-end of the beam: two lifting sets, each 26 inches diameter with a 9 feet stroke, raising water from the upper seam to the surface—a height of 339 feet. At the out-end of the beam: two lifting sets, 18 and 16 inches diameter respectively, with a stroke of 8 feet, raising water from the lower to the upper seam—a height of 345 feet.

On Plan No. I., Plate IV., an elevation of the bucket-door piece, to which the accident occurred, is shown. This piece formed part of one of the 26-inch sets which rested upon it. The crack was first visible as shown by the line XZ, and it afterwards extended as shown by the lines XZ and VW. It will be seen that the thickness of the metal forming the upper part of the pipe is $1\frac{3}{4}$ inches, and of that part where the circle is broken by the bucket door $3\frac{1}{2}$ inches, and $5\frac{1}{2}$ inches where the ribs are situated. At the top of the stroke the bucket just reaches the flange FF. The pressure of the column of water resting upon the bucket is 147 lbs. to the square inch, when not in motion. Taking this as the pressure upon the bucket and upon the bucket-door piece, the following is a calculation of what thickness the metal of the bucket-door piece should be to resist such a tension.

This piece, as will be seen, may be divided into two parts—the simple cylindrical pipe above the line AB (Plan No. I.) and the U-shaped doorway (see Plan No. 2) below this line.

The thickness of pipe to bear the given pressure will be found by the following formula ("Rankine's Rules and Tables"), $t = \frac{r \times p}{f}$

Where t = required thickness of pipe in inches.

r = inside radius of the pipe (= 13 inches).

p = pressure in lbs. per square inch on each square inch of the internal area of the pipe (= 147 lbs.).

f = working tension of cast iron in lbs. per square inch. Rankine states this to be one-sixth of the ultimate tenacity, and in this case it will equal $\frac{16,500}{6} = 2,750$

The calculation will then stand thus, $t = \frac{13 \times 147}{2,750} = 0{\cdot}695$ inches, being less than $\frac{3}{4}$ inch.

As this part of the bucket piece is $1\frac{3}{4}$ inches thick, it would appear to have a very ample margin for safety.

The calculation of the action of the pressure upon the part of the bucket-door piece, below the line AB, presents a problem of considerable difficulty.

On Plan No. 2 is shown a horizontal section of the bucket-door piece, in the line CD, on Plan No. I. It will be seen that the breaking strain, to cause the crack C, has been exerted in the direction shown by the arrows AA. As, however, the strong section of the pumps at the point *d* will add some strength to the doorway, it is clear that some part of the pressure of the column will be met by this part of the door piece. A vertical section of the front and back of the bucket piece is shown on Plan No. I. To arrive at the pressure which acts in the direction AA, it has been thought advisable to consider the section through the doorway as having to bear the full pressure of the column, and this may be expected to give, as fairly as can be arrived at, the resistance afforded by the section of iron actually presented; and as the section is so much less in the front than at the back, this mode of calculating will probably be on the right side, in not crediting the pump with more strength than it really has.

In this calculation, the strength of the whole of the bucket-door piece, from top to bottom, will be considered.

The total amount of tension exerted on the line of fracture will be as follows:—

h = total length of pipe subject to pressure (10 feet or 120 inches).

t = total sectional area of iron.

r = inside radius of the pipe. The average radius may be taken at 14 inches. As, however, the pipe in question is not a regular cylinder, the calculation will probably be more correct by taking $1\frac{1}{2}$ times the radius (= 21) to represent r.

The quantities p and f are the same as in the preceding formula.

Then $\dfrac{120 \times 21 \times 147}{2{,}240} = 165{\cdot}4$ tons.

And to arrive at t we have $\dfrac{165{\cdot}4 \times 2{,}240}{2{,}750} = 139{\cdot}7$ square inches of sectional area of cast iron to resist a tension of 165·4 tons in a height of 10 feet.

As the actual sectional area in this height is 170·6 square inches, it will be seen that this bucket-door piece can be taken as sufficiently strong if the statical pressure of 147 lbs. per square inch be considered to be the maximum pressure it has to resist, especially when it is remembered the figures 2,750 represent the *working*, and not the *breaking* tension of the cast iron forming the bucket-piece.

The result of these calculations is at least sufficient to show that the bursting of the bucket-door piece was caused by a pressure much greater than that due to the simple weight of the column of water. To form some idea what the actual pressure amounted to, a hydraulic gauge was attached to the bucket-door piece, at the point *h*, about 18 inches above the highest point to which the bucket rises. The record of the observations of this gauge may now be described.

The gauge was capable of indicating up to 800 lbs. on the square inch. The diagrams shown on Plates V., VI., VII., VIII., IX., show the results of five observations, each diagram exhibiting the indicated pressure of the water at different points of one complete stroke of the engine, under various conditions of working. As the gauge was not self-registering, the diagrams were made by carefully watching the pointer and noting the time and pressures, and each of the diagrams shown may be taken as a mean of at least 100 strokes under each condition.

It may be mentioned that the pipe from the pump to the gauge was made as short as possible.

The zigzag line on the diagrams represents the pressure of the column at different parts of one stroke, as shown by the gauge. The top line of the diagram represents the point at which the bucket reaches the top of the stroke. The vertical plain lines indicate divisions of 10 lbs.: and the horizontal lines divisions of one second.

The word "leave," below "top," signifies that at that instant the bucket commenced to descend; when the word "bottom" occurs, the bucket has reached the bottom of the stroke; and at the word "leave," it commences to ascend. Thus the time taken for each part of a stroke is given in each case. The black-dotted vertical line shows the statical pressure of 147 lbs. due to a column of water 339 feet high. It may be remarked, the conditions of working whilst the experiments were being made caused the balancing of the pumps at each end of the beam to be in favour of the up-stroke.

The diagram on Plate No. V. displays the action of the water whilst being pumped at a speed of 6½ strokes per minute, the engine working without being touched by the engineman. It will be observed that the minimum pressure is 120 lbs., and the maximum 215 lbs.

The effect of handling the engine in such a manner as to prevent the sudden termination of the up-stroke, is shown on Plate No. VI., where the speed is 6½ strokes per minute as with the first diagram on Plate No. V.; here the maximum pressure shown is 200 lbs., and the minimum 110 lbs.

To command the conditions under which the diagram on Plate No. VII. was taken, the engine had to move at the rate of 7½ strokes per minute. In this experiment the handles of the engine were dropped quickly in order to cause the up-stroke to end as suddenly as possible, and thus cause as severe a shock to the pumps as could be expected in ordinary practice. The result of this was to show a maximum pressure of 270 lbs. (and in one case of 300 lbs.), and a minimum pressure of 110 lbs.

On the diagram on Plate No. VIII. the result of a stroke at a speed of three strokes per minute is shown, and in this case the maximum pressure reaches 270 lbs., and the minimum 100 lbs.

The diagram on Plate No. IX. was taken also at three strokes per minute, but the engineman kept hold of the handles, thus regulating the engine. This shows a maximum pressure of 180 lbs., and a minimum of 120 lbs.

THE TABLE BELOW GIVES AN ABSTRACT OF THE RESULTS SHOWN ON THE DIAGRAMS.

No. of Diagram.	5.	6.	7.	8.	9.
Strain per Minute.	6½.	6½.	7½.	3.	3.
Condition of Working.	Ordinary.	Handled.	Handled to Cause Shock.	Ordinary.	Handled.
Reaching Top, min. ...	120	110	110	110	120
max. ...	215	200	270	270	180
Reaching Bottom, min.	130	130	135	130	130
max.	160	180	161	150	160

The above figures represent the pressure in lbs. upon the square inch.

The following observations may be made on the various points presented by these experiments :—

1. It will be seen that in every case, except when the engine is handled, the highest pressure occurs just when the bucket reaches the top of the stroke, and just when it arrives at the bottom.
2. It will also be seen that just when the bucket reaches the bottom of the stroke, and also at the moment it reaches the top, a suction occurs, varying from 17 to 47 lbs. less than the statical pressure of the column. The sudden rebound of the column of water at the bottom of the stroke, and the momentary movement upwards of the column on the conclusion of the up-stroke, are the probable causes of the slight suction.

3. The high and sudden pressure shown to take place the moment the bucket, at the top of the stroke, becomes at rest, is due to the fact that the water having acquired a momentum from the rising bucket, say of 5 feet per second, suddenly finds, when the bucket stops, the absence of an impelling force, and continues in motion for a fraction of an instant, then dropping on the bucket, giving the high and sudden indications shown.
4. The small movements of the pointer are probably only vibratory, being sequent to the heavy shocks.
5. It is important to notice, that all the high-pressures occur when the machinery is at rest, and hence, they do not influence the fuel economy of the engine to any extent worthy of note.
6. The proportion of time in the whole length of time occupied by the engine in the complete stroke, spent at rest, is interesting, as explaining one of the causes of the high velocity of the stroke.
7. The penalty of having an engine badly balanced is clearly demonstrated, since were the two ends of the beam equally balanced, the strokes might be more easily made to end slowly.

The most important fact, however, illustrated by these experiments, is the extreme suddenness of the heavy increase of pressure observable in every case, as occurring when the top of the stroke is arrived at; and the question naturally presents itself, "What does a rise of pressure from 110 to 270 lbs., occupying less, as nearly as could be judged, than a quarter of a second, actually represent as pressure upon the bucket and bucket-piece?" The pressure of 270 lbs. is clearly not dead weight, but acts as an impact or concussive pressure, and, as such, probably represents a much higher pressure than that indicated. It will be observed, on reference to the diagram on Plate No. VII., that the time taken by the up-stroke is two seconds, and as the length of the stroke is 9 feet, and its speed increases towards the completion of the stroke, the bucket may be considered to be arrested at the top of the stroke whilst moving at a velocity of five feet per second.

To obtain a correct solution of this question, the author communicated with Professor Rankine, to whom, together with Mr. W. R. Browne, he has to express his indebtedness. Professor Rankine, in his reply, states that, the total theoretical pressure due to the shock of the column, when checked in a velocity of five feet per second, is 595 lbs. on the square inch, but that the actual power will be less than the theoretical, owing to friction and other causes.

With some conditions of working, it is quite possible that the velocity of the column in reaching the top of the stroke will occasionally exceed five feet per second, and, hence, produce a higher concussive pressure.

To compare with the figure given above, it will be interesting to calculate the pressure which must have occurred to cause the breakage of the bucket door-piece through the line of rupture. The full sectional area of the front of the piece is, as before stated, 170·6 square inches.

The ultimate tenacity of cast iron is generally considered to equal about 16,500 lbs. per square inch. It was, however, well established by a Committee who reported upon the strength of iron as applied to railway structures, that when cast iron is subjected to a series of repeated shocks it always gives way in the end to a strain equal to about *one-third* part of that which would break it at the first application. In the case of shocks applied to cast iron in the form of a pipe, this may perhaps be taken at one-half.

Then $\frac{16,500}{2} \times 170 \cdot 6 = 1,442,000$ { Being the aggregate estimated pressure in lbs. upon the internal surface of the bucket piece.

Then, by the formula previously given :—

$\frac{1,442,000}{120 \times 21} = 572 \text{ lbs.}$ { Being the estimated pressure in lbs. per square inch on the internal diameter of pipe at the instant of fracture.

This result does not differ very materially from the figure 595, as given by Professor Rankine.

The above calculation is made from the pressures recorded in the diagrams, but it is quite possible that a much more serious shock may take place than those recorded, should some abnormal conditions of working the engine occur. The figure 572 appears to apply to the condition of things at the moment of fracture, and probably represents the pressure which a sudden rise from 100 to 300 lbs. in so short a time as a quarter of a second would amount to.

However far from accurate these calculations may be, the results they exhibit will serve to impress one of the objects of this paper—which is to illustrate the large margin of strength required in pumps where the mode of pumping allows the possibility of shocks similar to those described.

It will be seen above that the estimated pressure which has been the cause of the breakage amounted to 572 lbs. upon the square inch, or about *four times the statical pressure of the column.* Hence, taking the factor of safety as 6, it would seem advisable for pumps having similar shocks to have the bucket-door piece strong enough to resist 24 *times the bursting tension due to the statical pressure of the column of water they contain.*

On this basis the section of cast iron for safety in the case given should be $\frac{120 \times 21 \times 572}{2,750 \div 2} = 1130$ square inches, being more than six times the actual section, which was 170·6 square inches. The section required to resist a *breaking* tension will equal $\frac{1130}{6} = 188{\cdot}3$. The actual section of the bucket-door piece, ordered to replace the broken one, amounts to 358·6 square inches.

A few observations may be made on the bearing of the results of the experiments recorded upon the general economy of pumping water.

On reference to the accompanying diagrams, one of the chief evils of what may be termed "unbalanced" pumping engines is clearly manifest, viz., in the large proportion of time the engine remains at rest, the result being an increased velocity when in motion, thus accounting for the high speed acquired by the engine at the point of reaching the top or bottom of the stroke.

This points out the importance, firstly, of having as small a proportion of time as is possible occupied in the pauses between the up and down strokes, and, secondly, of endeavouring to arrange the motion of the engine so that the highest velocity is attained in the middle of the stroke, the beginning and end of the stroke being made at a slow speed.

With conditions of working equivalent to these, shocks would scarcely ever be felt, and such conditions are probably attained in three varieties of pumping engines :—

1. The Cornish engine.
2. The ordinary balanced beam engine, working lifting or other pumps, but working Rotatively by means of a fly-wheel.
3. The Direct-acting force pump with a short and frequent stroke, and with an air vessel attached.

The action of the Cornish engine forcibly illustrates the importance of the two points relating to the velocity of the engine referred to above. In Mr. J. B. Simpson's valuable paper on pumping engines he quotes the division of time taken in different parts of one stroke as given by Professor Pole.

This division is compared below with the experiments recorded on the diagrams :—

	Cornish Engine as per Pole. Seconds.	Unbalanced Engine as per Diagrams on Plates. Seconds.				
		3.	4.	5.	6.	7.
In-door or up-stroke of load ...	1·5	3·2	2·2	2·0	4·0	6·0
Pause	5	1·2	2·0	1·2	4·0	5·0
Out-door stroke	4·0	2·8	2·2	2·5	5·5	5·0
Pause	2·0	2·0	2·8	2 3	6·5	4·0
Total time in seconds	8·0	9·2	9·2	8·0	20·0	20·0

The short space of time taken by the Cornish engine in traversing the up-stroke would seem to indicate the occurrence of a shock at the beginning or end of the stroke, but the following analysis by Professor Pole, showing the velocity of each part of a 10-ft. stroke accomplished in 1·5 seconds, explains how this is avoided :—

1st	foot:	velocity,	5	feet per second (bottom of stroke).	
2	,,	,,	9	,,	
3	,,	,,	10	,,	
4	,,	,,	$10\frac{1}{2}$	,,	Steam cut off about this point.
5	,,	,,	$10\frac{1}{2}$	,,	
6	,,	,,	$9\frac{1}{2}$	,,	
7	,,	,,	$8\frac{3}{4}$	,,	
8	,,	,,	$7\frac{1}{2}$	,,	
9	,,	,,	$5\frac{1}{2}$	,,	
10	,,	,,	0	,,	

It will be seen that no shock can take place at the top of the stroke; and at starting from the bottom where the longest pause occurs, the column does not follow the ram, and hence no harm can result from the suddenness with which the stroke is commenced.

When a Rotary motion is imparted by a fly-wheel, only a very slight pause will take place at the termination of the up or down stroke, and as the time will thus be nearly all utilized in moving, the engine is able to obtain the same number of strokes per minute with a much less velocity of the piston.

The quick reciprocating action of Direct-acting force pumps, and the continuous stream they produce, tend to lessen the liability to shocks.

Experiments made with one pump of this class proved that the pressure did not vary more than 30 lbs. in a column 600 feet high.

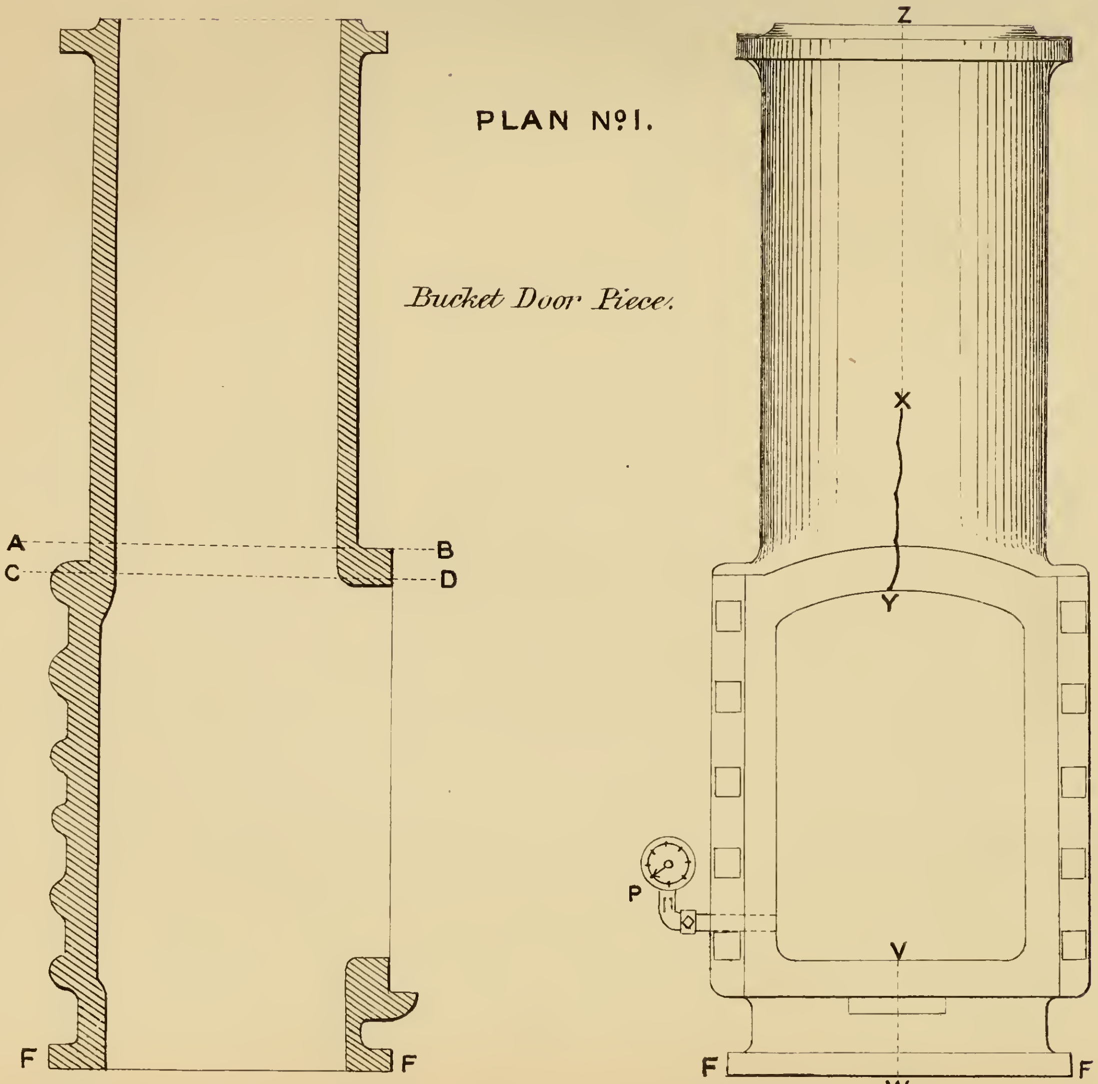
The author ventures, in concluding, to draw attention to the inadvisability (which has doubtless been recognised by many members of the Institute) in all cases where lifting sets are employed, of allowing the column of pumps to rest on the working barrel and wind-bore; thus rendering the removal of any part of the pump which may get broken a matter of great difficulty. If the pumps immediately above the bucket-door piece rested upon strong "buntons" fixed in the shaft, this difficulty would be overcome, and much time and expense would be saved in removing any part of the pumps below this point.

The SECRETARY added that when Mr. Cochrane had learned that Mr. F. W. Hall was going to read a paper "On the Settlingstones Pumping Engine," he had suggested the advisability of making some few observations there in confirmation or otherwise of Mr. Bainbridge's experiments. These experiments had been made and were appended to the paper, so that, possibly, it would be as well to read both papers and discuss them together.

The PRESIDENT asked if any gentleman had any remarks to make on Mr. Bainbridge's paper, which was certainly very interesting. He was not aware that anyone had personally gone so minutely into this point before; these indications of the weight of water in the pumps seemed to show the immense strain put upon them by the water settling back on the top at the clack, at the end of each stroke.

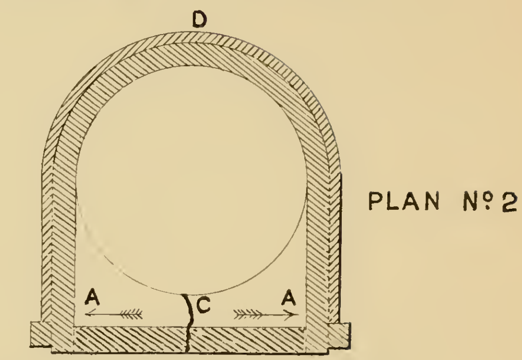
Mr. W. COCHRANE thought the Secretary's suggestion had better be adopted before any remarks were offered. The Settlingstones engine works a forcing set as well as a lifting set. Similar experiments had been made with both the sets; and if the two papers were considered as a whole it would be better.

To illustrate Mr. Bainbridge's paper "On the difference between the statical and dynamical pressure of Water columns in lifting sets."



Section and Elevation of Bucket Door Piece

HORIZONTAL SECTION.



Through Line C.D. on Plan No. 1.

Andw. Reid, Newcastle

To illustrate Mr. Bainbridge's paper "On the difference between the statical and dynamical pressure of Water columns in lifting sets"

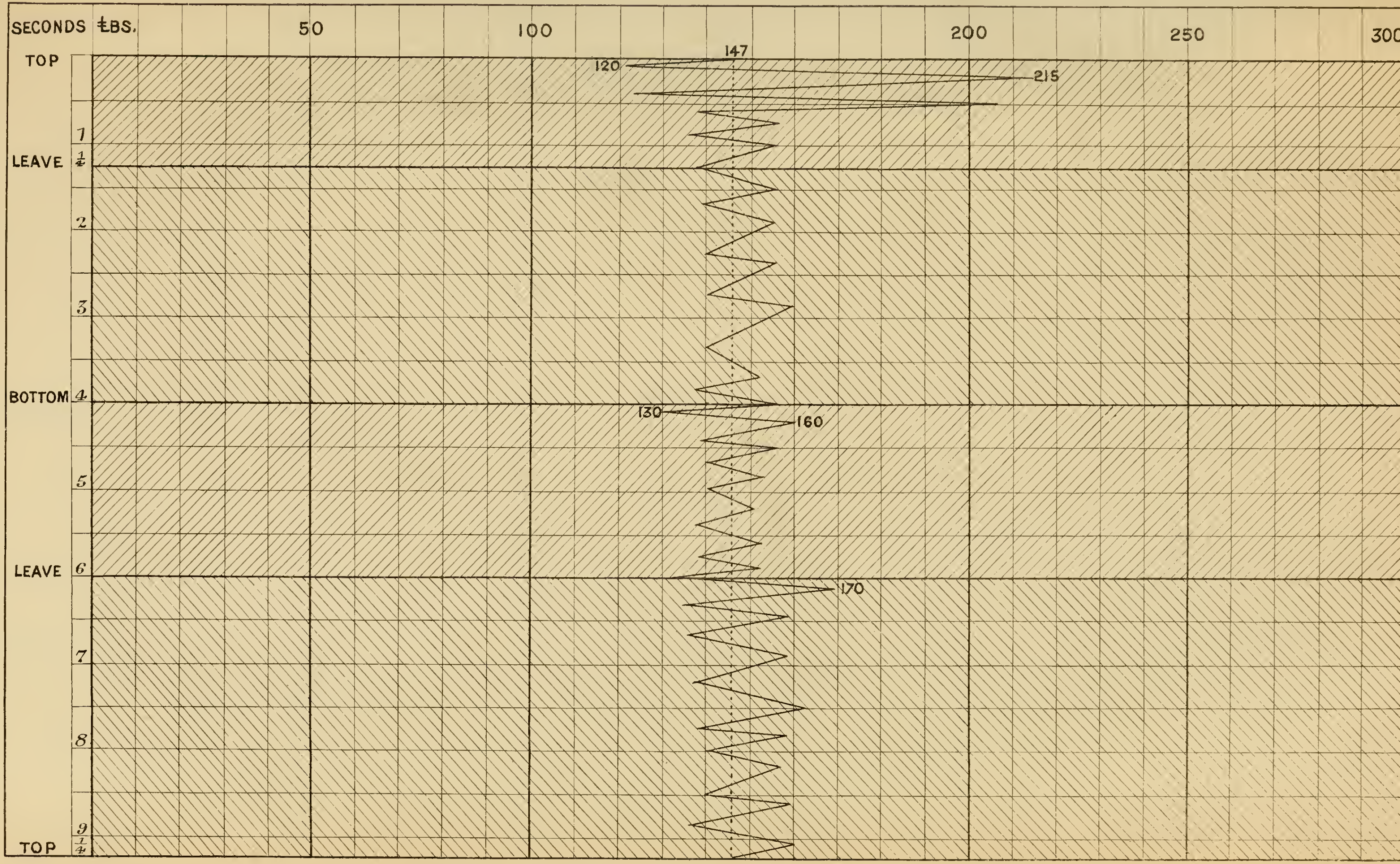


DIAGRAM SHEWING VARYING PRESSURE OF WATER IN ONE STROKE.

6½ strokes per minute: Working as usual.

To illustrate Mr. Bainbridge's paper "On the difference between the statical and dynamical pressure of Water columns in lifting sets."

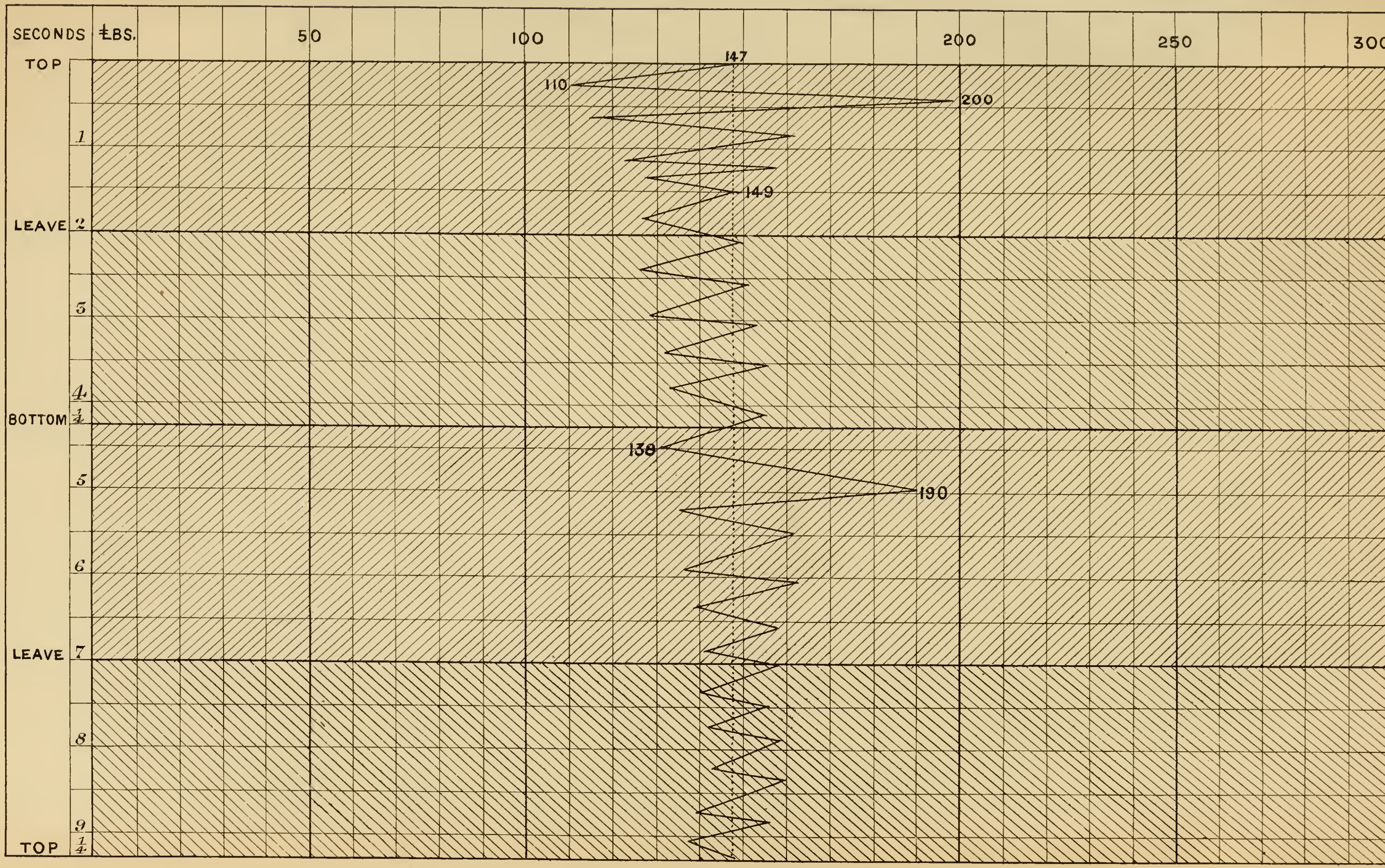


DIAGRAM SHEWING VARYING PRESSURE OF WATER IN ONE STROKE.

6½ strokes per minute: Handling the Engine.

Proceedings Nº E.I. of M.&M.E. 1871-72.

Andw Reid Newcastle

To illustrate Mr. Bainbridge's paper "On the difference between the statical and dynamical pressure of Water columns in lifting sets."

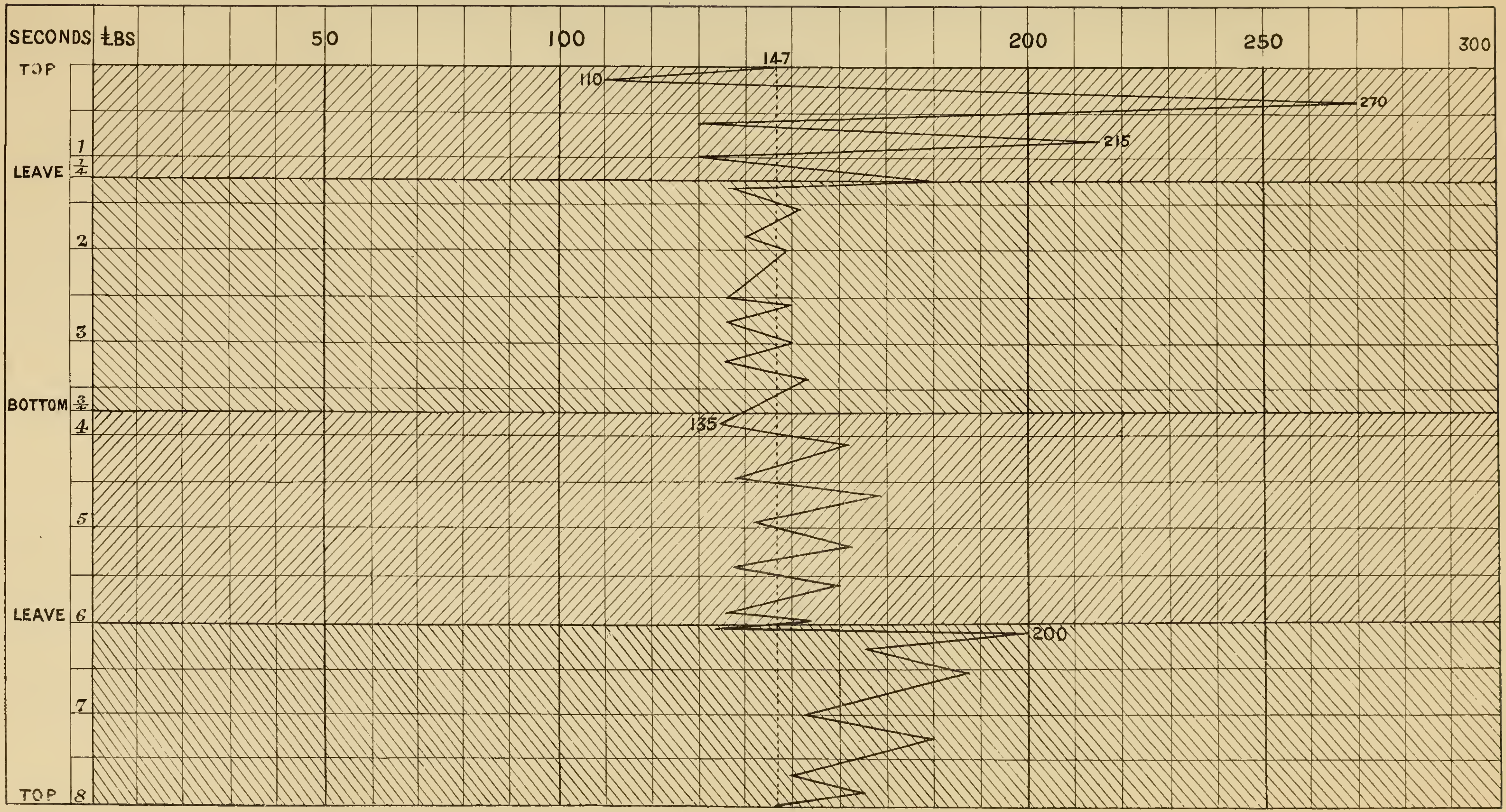


DIAGRAM SHEWING VARYING PRESSURE OF WATER IN ONE STROKE.

7½ strokes per minute: Working to produce heavy shock.

Proceedings No. E. I. of M. & M. E. 1871-72.

Andw. Reid Newcastle

pressure of Water columns in lifting sets.

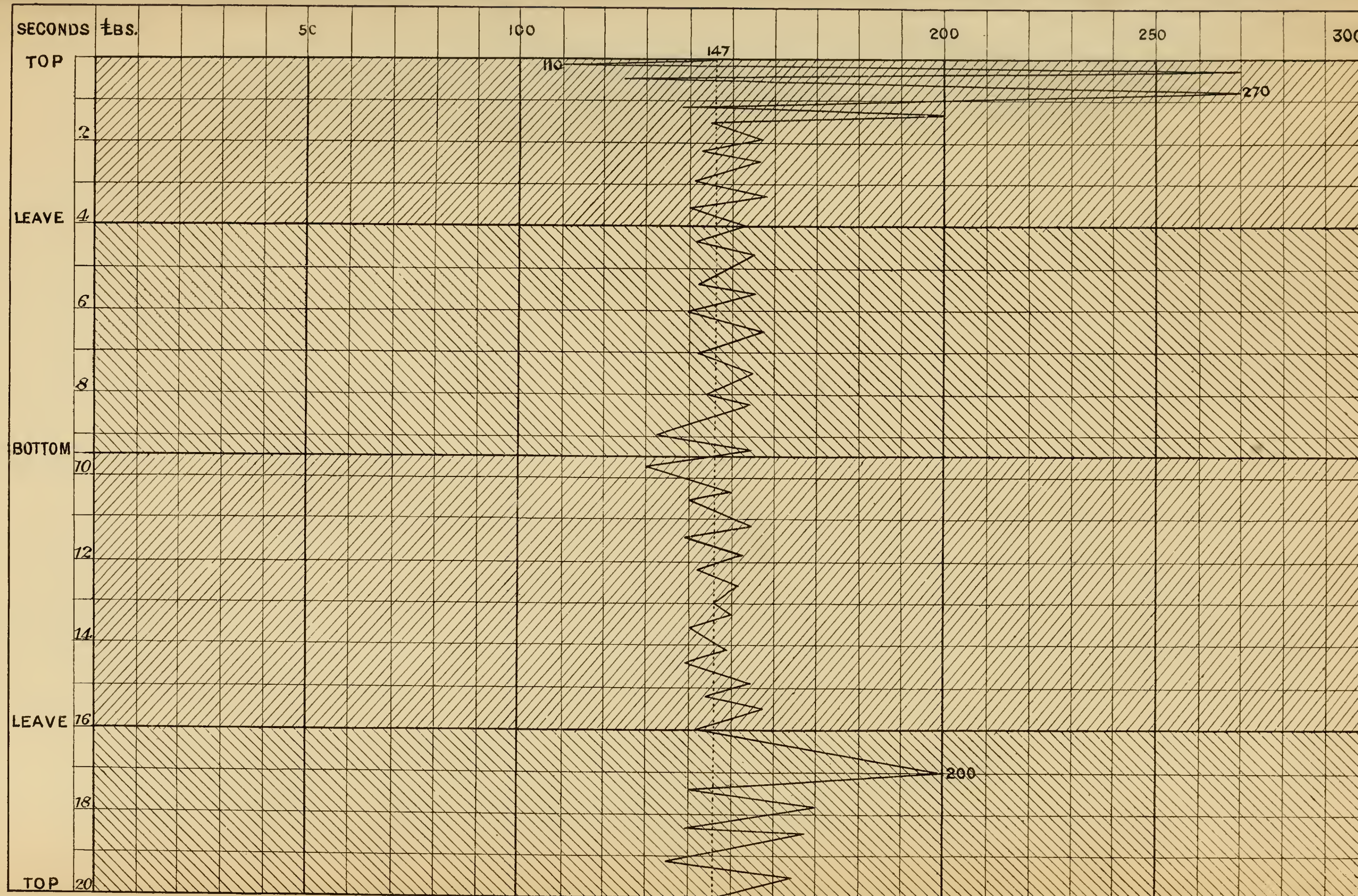


DIAGRAM SHEWING VARYING PRESSURE OF WATER IN ONE STROKE

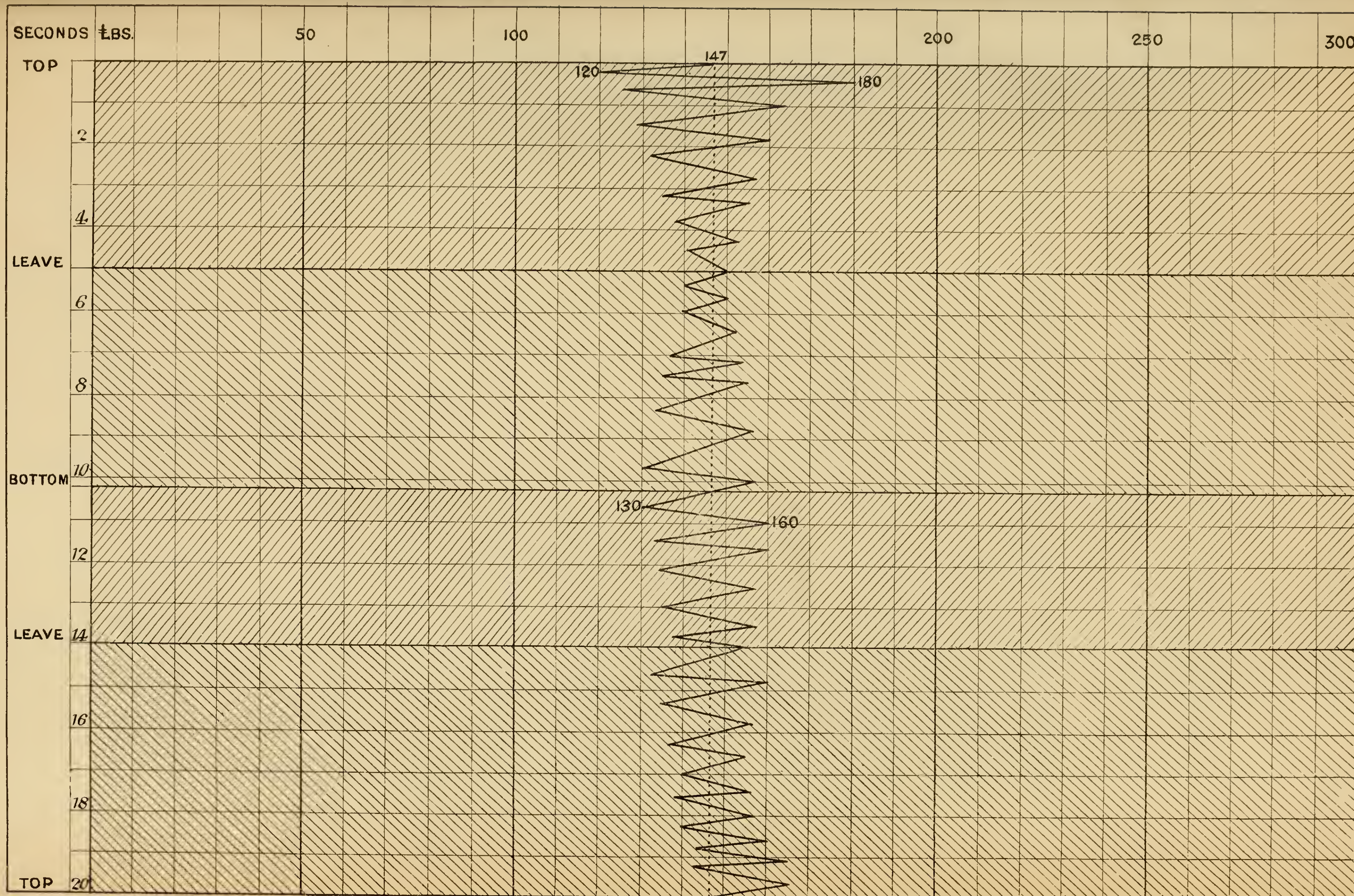


DIAGRAM SHEWING VARYING PRESSURE OF WATER IN ONE STROKE

THE CORNISH PUMPING ENGINE AT SETTLINGSTONES.

BY F. W. HALL.

THIS engine was made by Harvy and Co., Hayle Foundry, Cornwall, in 1864, was at work for six months at Chiverton Mine, after which it was removed, was purchased by Mr. Hall, brought by sea to Newcastle, and erected at the Lead Mine at Settlingstones in the year 1868, where it has been working ever since.

The engine is of the usual type of Cornish engine which is quite familiar to all engineers, and does not require any drawing to illustrate it. (See Plate 38, Vol. XIX., Page 202.)

The cylinder is 60 inches diameter, and is surrounded with a steam jacket covered with six inches of soil, cased with 9 inches of brick. The usual stroke of the piston is 10 feet.

The beam is 17 feet 4 inches long inside the house, and 15 feet 8 inches outside, giving a stroke of nearly 9 feet to the pumps.

The engine is worked by two double-flue Lancashire boilers 30 feet long, 7 feet diameter each, with two fire tubes 3 feet diameter. The fire-bars are 5 feet long. The flues are constructed in the ordinary way, and the boilers are covered with clay to a thickness of 12 inches above their tops.

The pressure of steam on the boiler is usually about 35 lbs. to the inch, and the gauge attached to the condenser stands at about $28\frac{1}{4}$ inches.

The engine makes about three strokes per minute, which is sufficient for the amount of work to be done, and at this speed developes about 36 horse-power, which is considerably within the power it could be made to exert.

Attached to the short end of the beam is a small 7 inch lifting set at the bottom pumping to 12 fathoms.

Next two $13\frac{3}{8}$ths lifting-sets pumping to 17 fathoms, and supplying the plunger set.

Again, one 18 inch plunger-set pumping to 37 fathoms.

It will be remarked that in the lifting-sets the weight of the two $13\frac{3}{8}$th columns per foot is 11·6 lbs. heavier than the weight of the single 18 inch column of the plunger-set, and as this 11·6 lbs. has to be lifted 102 feet, there is a loss of 1183 foot pounds per stroke.

These lifting-sets must, however, be somewhat larger than the single plunger-sets they supply, in order to prevent any possibility of the latter pumping on air at any time.

Two indicators about 4 feet apart were put on the forcing-set, one at A above the suction clack, and one at B above the delivery clack, Fig. 2, Plate X., and when at rest the pressure due to the column was found to be at A and B—95 and 93 lbs. respectively. Immediately after the plunger had finished its upward stroke, it fell 2 inches before it became at rest, and the pressure at A went up to a mean of 127 lbs., the extreme range of the pointer reaching 160 lbs. (Plate XI., Fig. 1), it then dropped to 95 lbs., remaining there till the end of the down-stroke, when it dropped to a mean of somewhere about 65 lbs., possibly through some small leakage of the suction valve; during the up-stroke the pressure became nil.

The vibration of the pointer was probably caused by its *vis viva*, after receiving a sudden shock.

The gauge at B reached an average of about 119 lbs. (Plate XI., Fig. 2), the extreme range of the pointer going up to 145 lbs., when the plunger was at the top-stroke, and came down to 93 lbs. before it began to descend, it remained there during the descent of the plunger, and then suddenly dropped about 20 lbs. as the plunger came to rest, going up to 93 lbs. during the rest at the bottom and the upward stroke.

Two indicators were similarly placed (see A B, Fig. 3, Plate X.), about 13 feet apart in the lifting-set, and the static pressure due to the column was found to be 37 and 30 lbs. at A and B respectively.

Immediately after the bucket had finished its upward stroke, it fell 2 inches before it became at rest, and the pressure at A went up to a mean of 62 lbs. (Plate XII., Fig. 1), the extreme range of the pointer reaching 87 lbs., it then dropped to 37 lbs., remaining there till the end of the down-stroke, when it fell to 32 lbs., probably through some small leak in the suction valve; during the up-stroke the pressure became nil. The guage was remarkably steady after the bucket began to descend.

The guage at B reached an average of about 49 lbs. (Plate XII., Fig. 2), the extreme range of the pointer going up to about 68 lbs., when the bucket was at the top-stroke, and came down to 30 lbs. before it began to descend: it remained there during the descent of the bucket and the rest that followed, and then suddenly rose to about 53 lbs. on an average, the extreme range of the pointer going up to about 75 lbs., when the bucket began to ascend.

The indicator diagram, taken from the cylinder Fig. 1, Plate X., shows that the steam never rises above 16 lbs. to the inch, although the pressure

DIAGRAMS TO ILLUSTRATE MR F. W. HALL'S PAPER ON THE SETTLINGSTONES ENGINE.

Indicator Diagram taken from Engine 3/4ths full size.

FIG. I.

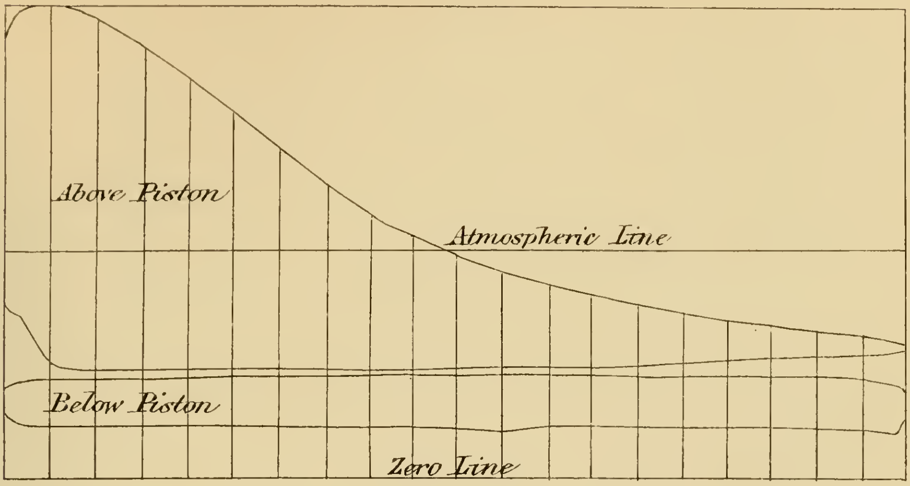


DIAGRAM
Shewing position of Gauge on Forcing Set.

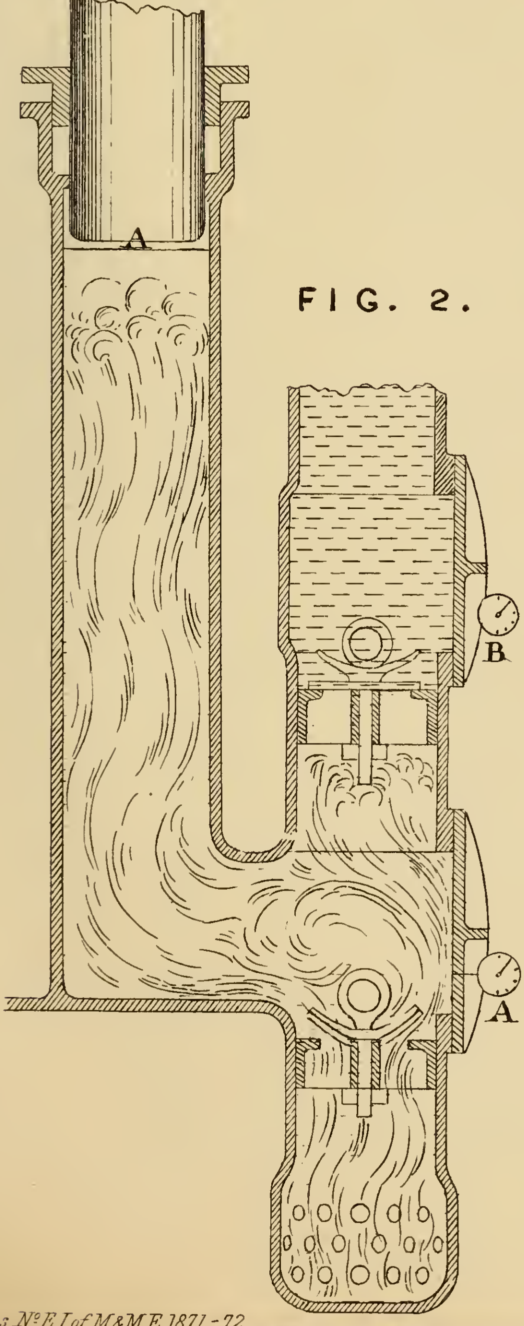


FIG. 2.

DIAGRAM
Shewing position of Gauge on Lifting Set.

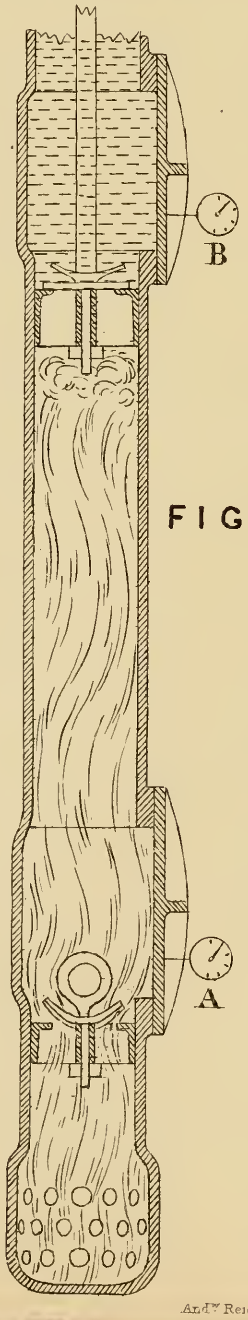


FIG. 3.

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DIAGRAMS TO ILLUSTRATE Mr F. W. HALL'S PAPER ON THE PUMPING ENGINE AT SETTLINGSTONES

FORCING SET.

FIG. 1.

Indicator above suction Clack.

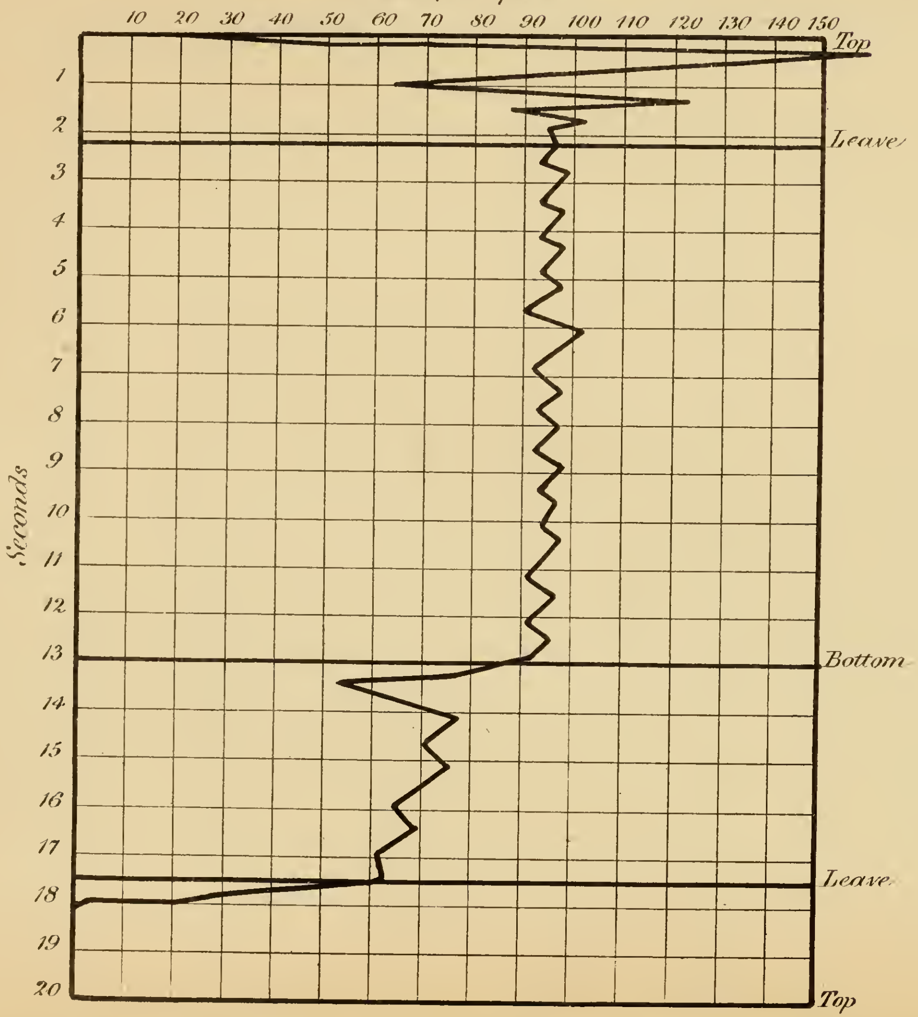
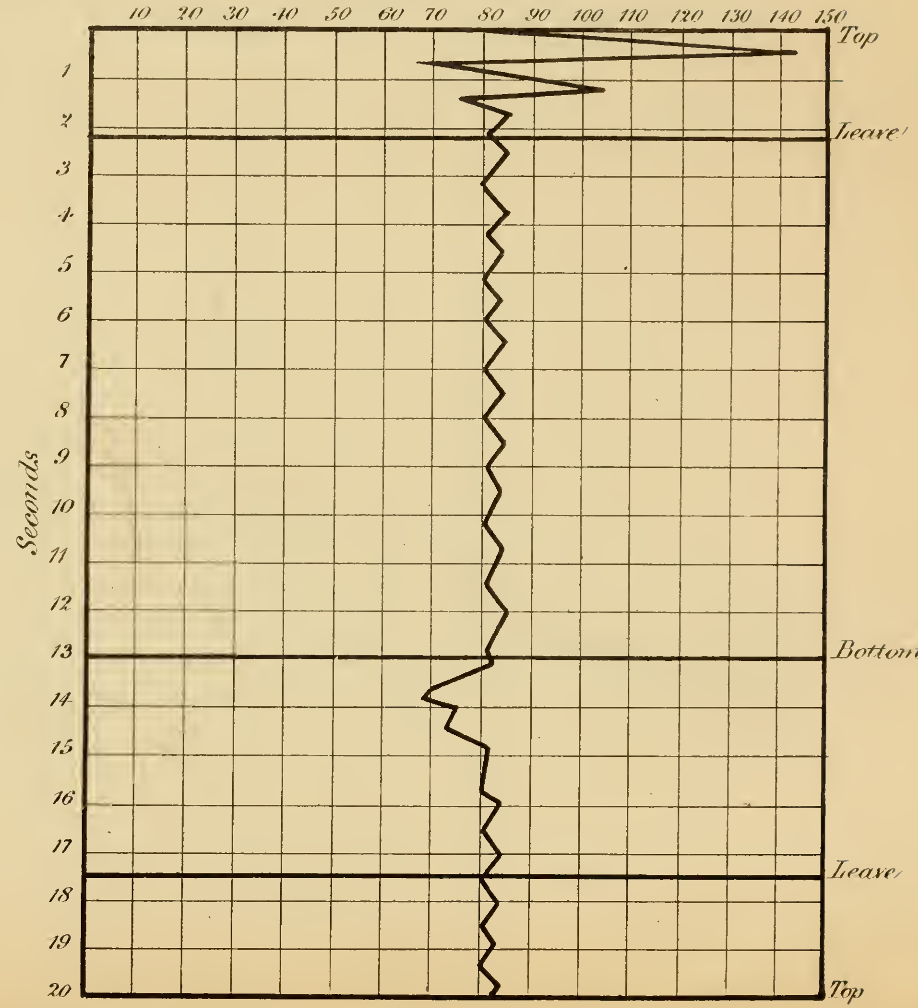


FIG. 2.

Indicator above delivery Clack.



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DIAGRAMS TO ILLUSTRATE Mr F.W. HALL'S PAPER ON THE PUMPING ENGINE AT SETTLINGSTONES.

LIFTING SET.

FIG. 1.
Indicator below Bucket.

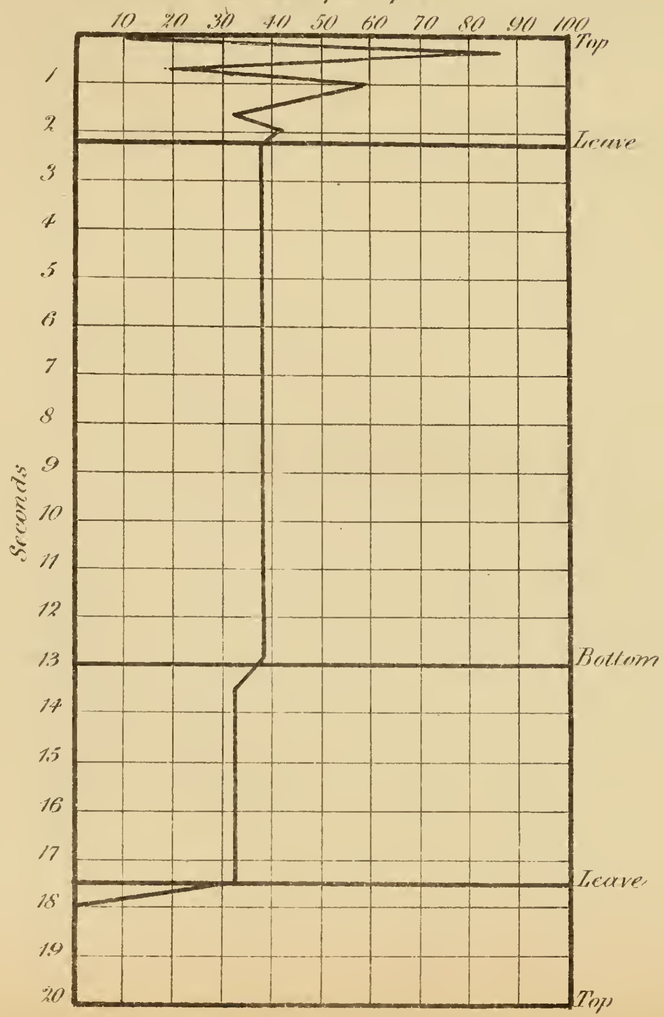
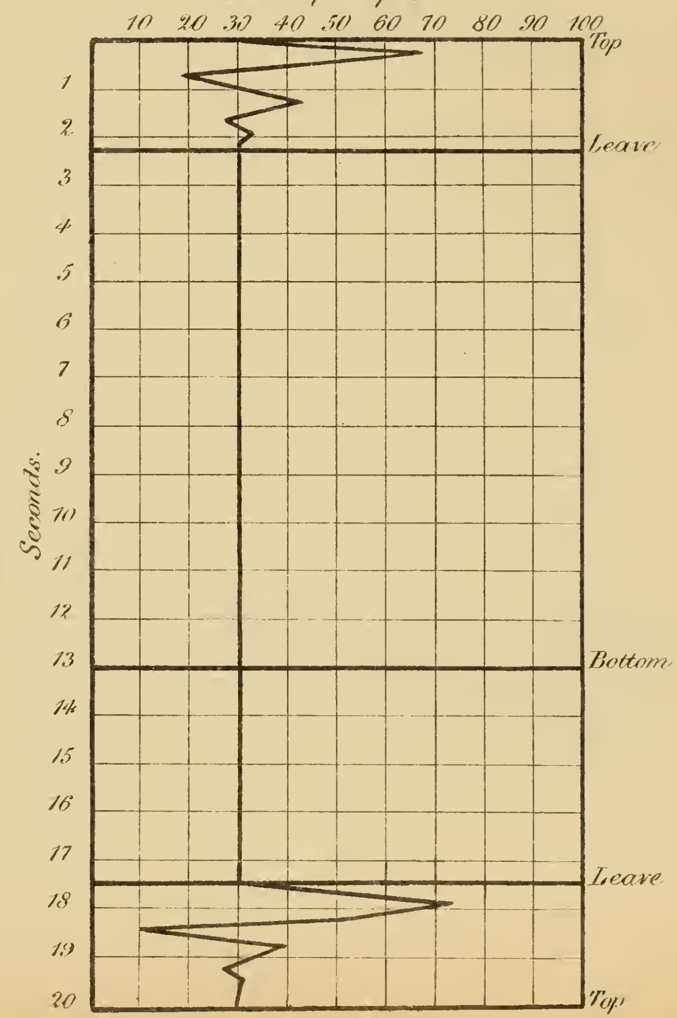


FIG. 2.
Indicator above Bucket.



And^w Reid Newcastle

in the boiler is 35 lbs. The throttle valve, which is 8 inches diameter, and which to give its fullest area should open 2 inches, is in fact only opened $\frac{3}{8}$ths of an inch. It would seem, therefore, that a greater economic effect would be produced by cutting off still earlier and keeping the throttle valve full open. But the insufficient size of the suction clacks of the lifting-sets prevents this being taken advantage of. The vacuum in the cylinder is also not so good ($11\frac{1}{2}$ lbs.) as might be expected from the indication of the gauge 14 lbs., owing to the packing of the piston having been somewhat worn at the time the experiments were made; otherwise the diagram is most excellent, and gives at three strokes per minute 35 horse-power. The feed water is usually at a temperature of 60°.

The economical working of the apparatus is not, however, in the application of the steam but in its production. The principles of slow combustion are carried out so fully that in bright sunshine it is difficult to see if the fire is alight or not.

In an experiment during 32 hours, the engine counter giving 5,640 strokes, 26 cwts. of small semi-bituminous coal from Fourstones Colliery were burnt, which is equal to ·516 of a pound of coal per stroke of engine.

There was no direct means of ascertaining the exact quantity of water evaporated during this time, but if the water is calculated from the pressure, volume and quantity of steam used per stroke, theoretically the amount, though not exact, will err on the safe side; that is, practically, more water will be used than the calculation will give.

At the end of the stroke the pressure of steam above zero is 9·5, which gives a volume of 2551. The cubic contents of the cylinder (196 feet) divided by this gives ·0770 cubic feet of water, or 4·8 lbs., or adding 5 per cent. for passages, 5·052 lbs. of water evaporated by ·516 lbs. of coal, or 9·78 lbs. of water at 60 degrees, evaporated by one pound of small coal, or 10 lbs. of water at 100 degrees, the Government standard, taking the latent heat of steam at the pressure of the atmosphere at 988 degrees. This result is most exceptionably good, and will compare most favourably with the best result obtained by the Governments at Devonport in 1863. (See Transactions, Vol. XIV., which gave 10·71 lbs. of water at 100° to 1 lb. of Davidson's best Hartley, burnt in an ordinary marine tubular boiler without cleading.

When using large splint from Mickley this result was reduced to 9 lbs. of water at 100 degrees per pound of coal.

The following table gives a comparison between this engine and the Cornish engine described by Mr. Simpson in Vol. XIX., pages 203 and 219:—

	Diameter of Cylinder.	Stroke in Cylinder.	Stroke in Pit.	Number of lifts and description.	Length of lifts in fathoms.	Diameter of Pumps.	Load in Pit.	Strokes per Minute.	Gallons per Minute.	Time of Experiment.	Coals consumed.	Indicated Pressure.	Effective Horse-power.	Indicated Horse-power.	Loss of Power.	Per centage of useful effect.	Lbs. per H.P. per hour effective duty.	Lbs. per H.P. per hour indicated duty.	Millions of lbs. lifted 1 foot high with 112 lbs. of coal.	Gallons lifted 100 yards with a ton of coal.	Number of Boilers.	Size of Boiler.	Cost per annum of 100 H.P. of effective duty.	Cost per annum of 100 H.P. of indicated duty.	Time Engine has worked—Years.	Lbs. of water evap. from 60° with 1 lb. of coal.	Lbs. of water evap. from 100° with 1 lb. of coal.
										hrs.	T. c. q. lbs												£	£			
HEBBURN— Cornish Engine	70	$9\frac{11}{12}$	$7\frac{1}{12}$	1 Plunger 1 do. 1 do. 1 Bucket	38 40 36 6	21 18½ 18½ 19	88,695	7·03	829	12	5 16 0 0	22·7	149·16	184·5	35·3	80·7	3·6	2·93	61·28	407,371	3 Cornish	34 × 6·9 tube 4·3	283	230	5	..	..
SETTLINGSTONES— Cornish Engine— Splint Coal	60	10	9	1 Plunger 1 Bucket 1 do. 1 do.	37 17 17 12	18 13⅜ 13⅜ 7	38,000	3·05	301	120	5 14 0 0	14·1	31·6	36·7	5·1	86·	3·37	2·9	65·94	439,600	2 Lancashire	30 × 7	262	226	..	8·7	9
SETTLINGSTONES— Cornish Engine— Small Coal	60	10	9	do.	do.	do.	38,000	2·94	291	32	1 6 0 0	14·1	30·4	35·5	5·1	85·6	3	2·56	74·22	494,800	2 Flued	Tube 3 ft.	233	197	..	9·78	10

On reference to Vol. XVII., page 22, it will be found that Mr. Steavenson stated that Mr. Henwood, at Huel Towan, after measuring the actual quantity of water delivered by a pump, estimated the deficiency at 7 to 8 per cent. of the calculated contents of the pump, and that from experiments of his own his deficiency ranged from 4 to 10 per cent.

This offers an explanation to the various pressures observed in the gauges placed in the pumps at the various portions of the stroke given in the table.

From many causes it is absolutely impossible, during the time occupied by the stroke, to fill with water a space suddenly exhausted by the rapid sweep of a bucket or a plunger.

In the case of the ascent of the bucket, as described, the whole column rests on the rods till the return stroke; and, at the moment of reaching the top, a rising column is rushing up through the suction valves towards the bucket.

At this point the bucket and the column resting on it drops suddenly two inches and meets the column of water rushing into the pump, which it strikes with great violence and produces the extraordinary pressure indicated, which in this case is 1·7 times the static pressure due to the column.

Precisely the same result is obtained when the plunger of the forcing-set drops the two inches and meets the water rushing up through the suction valve, producing a pressure in this case 1·3 times that due to the static pressure of the column. It will be remarked here that the blow takes place at a time when the column above the delivery valve is and has been at rest for some time.

There is, however, a physical difference in the nature of the two blows, the one caused by the free fall of a heavy column of water so many inches striking a column rising at the rate of possibly 5 or 6 feet a second with little or no elastic medium between them; the other, the blow of a certain weight of plunger and spear more or less balanced and restricted in velocity.

The effect of this is seen in the pressure increasing 1·7 times with the bucket, and only 1·3 times with the plunger at the turn of the stroke.

The causes which prevent a pump from filling itself perfectly full at each lift are various. Amongst others,

1st.—The suction clack valves fall as soon as the stroke is completed, and during the fall a certain portion of water falls with them.

2nd.—The friction of the water entering the snore holes.

3rd.—The sufficiency of the packing of the bucket.

The loss from these causes may be all increased by bad proportions.

There is one remedy which is generally most effective in preventing the violent blow caused by the return stroke, viz., the admission of a small quantity of air into the pump at each stroke. This can be effected either by a separate valve admitting the air but preventing the water from flowing out during the return stroke, or, in the case of a plunger, by slacking the stuffing box.

All pumps connected with fast working engines, such as are used on board ship, are provided with such valves, the absence of which would produce serious damage.

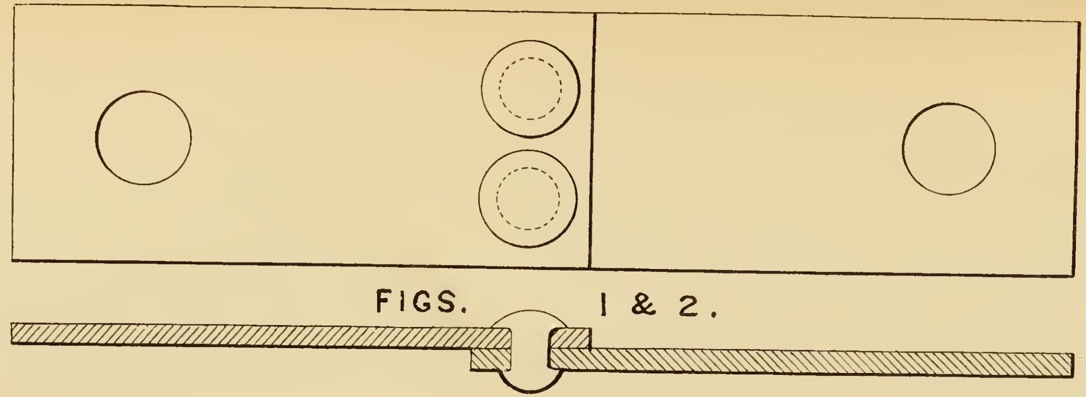
In conclusion, the author has endeavoured to describe fully the whole of the circumstances under which the engine performs, and will be most happy to add any further particulars that may be suggested during the discussion, if they can be practically arrived at.

Mr. J. B. Simpson said, with respect to Mr. Bainbridge's paper, two or three years ago he made some experiments, not with the bucket-set, but with the plunger-set, with a result similar to what Mr. Bainbridge had stated, that was to say, that instead of the normal pressure due to the column of, say, 147 lbs., be found in several instances at the beginning of the strokes in the plunger pumps almost 50 per cent. more than was due to the column. At that time, he thought it was owing to the imperfection of the gauge with which he arrived at the result, and made no further experiments; besides there was no appreciable effect upon the engines, such as would have been the case, if the pressure which was indicated by the gauge was to be overcome by them; that is, if an engine doing a certain amount of work, out of which 80 per cent. duty was obtained might in reality be found to give more than 100 per cent. if the increased pressure denoted by the gauge were to be taken into the calculation, and as this could not take place, he thought it was due to some question of velocities more than to any question of pressure which affected the engine. There was another point which, he thought, ought to be borne in mind with respect to the bucket door pieces, and that was their shape. He had had several door pieces broken, and in making new ones he had altered the shape of the curves; for instance, the bucket door piece shown in Plate IV., Fig. 2, he should say was too square in the interior part, and should be rounded about to produce as great a strength as possible; the thickness of the iron was not always the only element in the question. With regard to the Settlingstones engine, the results obtained seemed to be a little better than he had got, but his (Mr. Simpson's) experiments had perhaps extended over a longer time. During these four months, the actual duty got out of the engine at Hebburn was about 4 lbs. per horse-power, per hour; the indicated duty about 3·6. The lowest experimental indicated duty he had had was 2·6 lbs. per horse-power per hour. He might say that at the present moment the duty of their engine at Hebburn, if they were to use the coal ordinarily used by the pumping engines in this district, would cost them £2000 a year more than it did at the present time. They were pumping about 700 gallons per minute from a depth of 120 fathoms; and he thought this was a practical application of the utility of the Cornish engine.

Mr. Steavenson said, the question treated of in these two papers was very similar in its nature to that brought forward by Mr. Daglish, of the raising of cages. The power required to lift a certain number of gallons, or a certain number of pounds, can easily be ascertained, and that might be called the useful work; to this is to be added the friction, which is easily ascertained according to the laws of the flow of water in pipes; thirdly, the force of the *vis inertia*, considered in this way, and studied it in the light of these laws, it would be ascertained that the experiments which had been made would be simply in agreement with those laws. The laws of *vis inertia* depend upon the relation of the mass of matter to its velocity, and the experiments which had been now shown were a mere practical illustration of those laws which had already been ascertained by similar experiments. There was a General Morin, in France, some time about thirty or forty years ago, who went into and very fully investigated this subject, and any one studying his works would see very much the same as they had had illustrated there that day. He did not mean to say that he did not think the subject was well worthy of attention, and that they were not very much obliged to the gentlemen who had brought a subject practically before them which was very often overlooked. The question as to the fly-wheel upon the engine was one which he had on previous occasions spoken upon. There was no doubt that if water was to be moved at a certain regular velocity the fly-wheel was advisable; but if there is sufficient capacity of pump and power of engine, the slower the pump works the better; and for his own part he preferred to see an engine come to rest each stroke. Observe a bucket when delivering a great body of water at a great depth; we see that the water continues to flow after the engine has ceased to move. They had there the work of the *vis viva;* and he believed it was possible to prove that a pump well adapted and perfectly made would deliver more water than its capacity would lead us to expect. As they proceeded in the discussion, he should be glad to illustrate his views farther, if necessary. Much, too, of these remarks applied in a similar manner to Mr. Daglish's paper. There was no doubt that when they came to discuss that paper, the laws of *vis inertia* and of *vis viva*, which apply to the raising of weights at certain velocities, would be found to explain the diagrams which they had now brought before them.

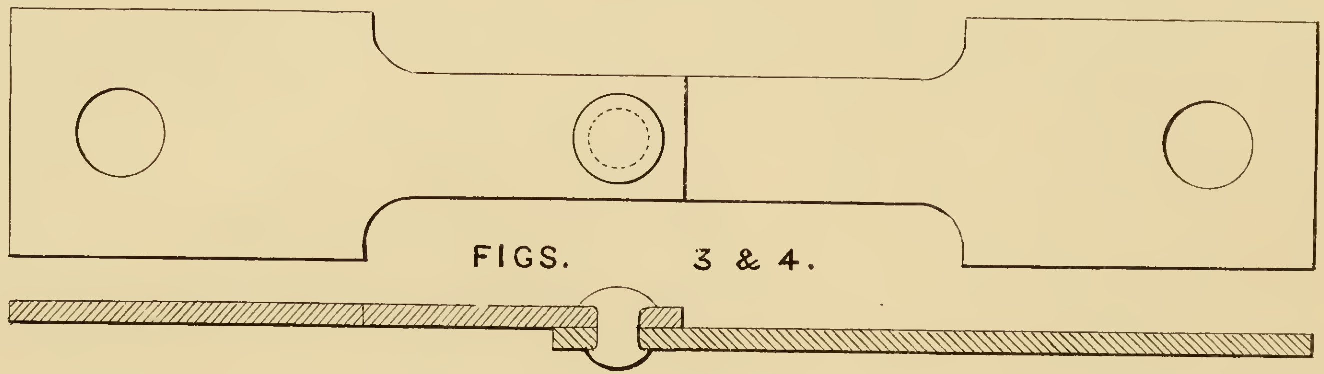
The discussion on Mr. Daglish's paper was adjourned, and the meeting separated.

Diagrams to illustrate the report on rivetting with Drilled and Punched holes.



FIGS. 1 & 2.

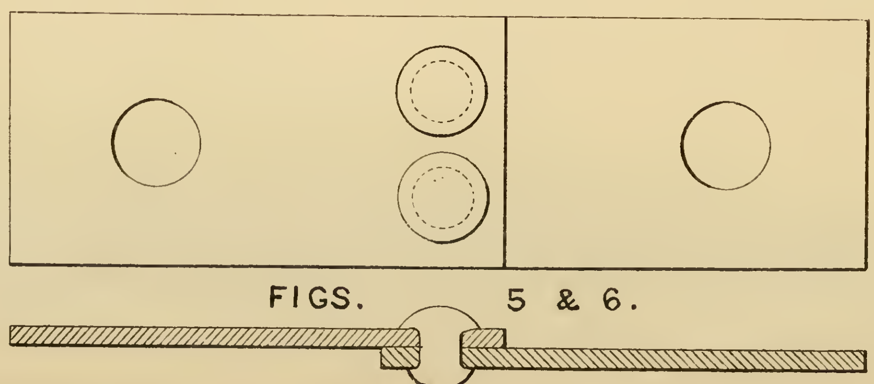
Plates secured by double rivets supplied by Mess.rs J & G. Joicey.



FIGS. 3 & 4.

Plates secured by single rivet supplied by Mess.rs J & G. Joicey

Scale 3 ins = 1 foot.



FIGS. 5 & 6.

Plates secured by double rivets supplied by Mess.rs Thompson, Boyd & C.o

And.w Reid Newcastle

REPORT UPON EXPERIMENTS OF RIVETTING WITH DRILLED AND PUNCHED HOLES, AND HAND AND POWER RIVETTING.

In the experiment made before the April meeting, and then described, the plate broke in the punched holes under a load of 18 tons, being 18 tons 2 cwts. per square inch of sectional area of plate, and 17 tons $9\frac{1}{2}$ cwts. per square inch of rivet. In this joint the widest part of the punched hole was found to have been laid to the other plate, thus giving an inferior bearing for the rivet. Plate XIII., Figs. 1 and 2.

The second experiment with the drilled seam, after having been subjected to the strain as above, did not carry the load of 15 tons, one plate being broken across and the other cracked at both sides. Though this was a double experiment, they are both noted in the table. Plate XIII., Figs. 1 and 2.

In experiments Nos. 3 to 8 inclusive the strips were planed at the sides to about 2 inches wide, or the average pitch of the rivets in boiler work, and the holes were formed in the middle, care being taken to keep the drilled holes as nearly the same area as the punched holes as possible. AA and EE were drilled, BB and DD were punched, C1 and F1 were punched, and C2 and F2 were drilled, the former, C1, being left to be filled by the closing of the rivet, the latter, F1, receiving the shoulder of the rivet. No. 3 was begun with too great a load, and the rivet was sheared at once. The other five strips also gave way at the rivet, the greatest strain being 18 tons $14\frac{3}{4}$ cwts. borne alike by CC and DD. The least strain was 16 tons 6 cwts. per square inch of rivet, giving an average, on the five tests, of 17 tons 9 cwts. per square inch of section of rivet. The greatest load carried by the plate was 21 tons 6 cwts. per square inch, and also by CC and DD; the least, 18 tons $1\frac{3}{4}$ cwts., or giving the average of 19 tons $8\frac{3}{4}$ cwts. per square inch of sectional area of plate. Plate XIII., Figs. 3 and 4.

In the experiments 9, 10, 11, the plates broke through the rivet holes, the punched plate carrying 18 tons 12 cwts. strain per square inch. No. 11 is valuable as showing the relative value of holes that are not punched fairly, showing a considerable diminution of strength. The average of the three experiments was 17 tons 16 cwts. as the ultimate strain per square inch of plate, and 15 tons $1\frac{1}{4}$ cwt. per square inch of rivet in sectional area, carried without fracture. Plate XIII., Figs. 5 and 6.

In experiments 17, 18, one rivet only was sheared in each, showing the average breaking strain of 17 tons 11 cwts. per square inch of sectional area of rivet and 18 tons 15½ cwts. per square inch as the strain on the plate. Plate XIII., Figs. 5 and 6.

The other experiments were defective from giving way in the coupling eye, and are therefore not given; but it was intended to complete the series had not the preparation of the bars by the same parties been prevented hitherto. Arrangements are now being made for verifying those already made, as well as for extending the set, which will prove valuable for reference.

The comparison between hand and machine work being incomplete, the results cannot be taken into account.

The deductions from the above may be briefly summed up:—(1) That punched holes have not been found to be inferior to drilled holes; (2) That the breaking strain of the plate when new is greater than that of the rivet per square inch of sectional area; and (3) That the influence of bad workmanship upon the strength of a seam is more than is generally admitted, and as a rule drilled holes would be more accurate and less likely to overlap than punched ones.

ABSTRACT OF TABLE OF RIVETTING TESTS.

Maker.	Experiment.	Punched.	Drilled.	Work.		Remarks.	Breaking Strain per Square Inch.	
							Plate.	Rivet.
Joicey	1	1·2	2·3	Single Lap	Hand	Broke in the punched holes	18·2	......
„	2	......	2·3	„	„	Gave way at once, both plates fractured	15·1¾	......
„	3	......	A A	„	„	Rivet sheared at once ...	......	23·6
„	4	B B	......	„	„	Rivet sheared	......	16·19¾
„	5	C 1	C 2	„	„	Rivet broken, C1 plate cracked ...	21·6	18·14¾
„	6	D D	......	„	„	Rivet sheared, plate slightly cracked	21·6	18·14¾
„	7	......	E E	„	„	Rivet sheared	......	16·6
„	8	F 1	F 2	„	„	Rivet sheared	......	16·10
Boyd	9	C	......	„	„	Broken in rivet holes ...	18·12	......
„	10	......	D	„	„	„ „ ...	17·17	......
„	11	E	......	„	„	„ „ ...	16·19	......
„	17	......	L	„	„	One rivet sheared ...	......	17·4⅔
„	18	......	M	„	Machine	„ „ ...	......	17·17¼

RESULTS OF EXPERIMENTS WITH PUNCHED AND DRILLED SEAMS CLOSED BY HAND AND POWER.

Maker of Bar for Experiment.	Number of Experiment.	Rivet Holes.		Kind of Seam.		Sizes of Plates.		Rivets.		Sectional Area of Plate.		Testing Loads.			Breaking Strain per Square Inch.		Remarks.	Load borne per Square Inch at time of fracture.	
		Pchd.	Drlld.	How Laid.	Work.	No. 1.	No. 2.	Number.	Area.	No. 1 Plate.	No. 2 Plate.	First Load.	Greatst borne.	Broke under.	Plate.	Rivet.	Result of Experiment.	Plate.	Rivet.
						Inches.	Inches.		Sq. In	Sq. In	Sq. In	T. C.	T. C.	T. C.	T. C.	T. C.		T. C.	T. C.
Joicey	1	1·2	2·3	Single Lp	Hand	3·937×0·43	3·937×0·43	Two	1·03	0·994	0·994	15 0	17 18	18 0	18 2	....	Broke in the rivet holes of the punched seam	....	17 9½
do.	2	..	2·3	do.	do.	3·875×0·43	3·94 × 0·43	do.	0·883	1·021	1·032	15 0	....	15 0	15 1¾	....	Both plates of drilled seam broken, in former trial would not carry 15 tons	....	14 11¼
do.	3	..	A A	do.	do.	2·05 × 0·38	2·05 × 0·38	One	0·515	0·470	0·470	12 0	....	12 0	....	23 6	Rivet sheared at once	....	....
do.	4	B B	..	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 13	8 15	....	16 19¾	Rivet sheared	18 12⅓	....
do.	5	C 1	C 2	do.	do.	do.	do.	do.	do.	do.	do.	8 0	9 10	9 13	21 6	18 14¾	Rivet broken, C 1 plate cracked in two places, and rivet head torn off C 2	21 6	....
do.	6	D D	..	do.	do.	do.	do.	do.	do.	do.	do.	8 0	9 10	9 13	21 6	18 14¾	Rivet sheared, plate slightiy cracked ..	21 6	....
do.	7	..	E E	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 5	8 8	....	16 6	Rivet sheared	17 17½	....
do.	8	F 1	F 2	do.	do.	do.	do.	do.	do.	do.	do.	8 0	8 8	8 10	....	16 10	Rivet sheared	18 1⅔	....
Boyd	9	C	..	do.	do.	3·9 × 0·39	3·9 × 0·37	Two	1·03	0·887	9·841	12 0	15 10	15 13	18 12	....	Broke through rivet holes in No. 2 plate	....	15 3¾
do.	10	..	D	do.	do.	3·9 × 0·40	3·9 × 0·37	do.	do.	0·910	0·841	12 0	16 3	16 5	17 17	....	Broke through rivet holes in No. 1 plate	....	15 15½
do.	11	E	..	do.	do,	3·9 × 0·38	3·9 × 0·38	do.	do.	0·864	0·864	12 0	14 10	14 13	16 19	....	Punched blind, broke through rivet holes	....	14 4⅓
do.	17	..	L	do.	do,	4·3 × 0·36	4·3 × 0·36	do.	do.	0·963	0·963	12 0	17 13	17 15	....	17 4⅔	One rivet sheared	18 8⅔	....
do.	18	..	M	do.	Mchn	4·3 × 0·36	4·3 × 0·38	do.	do.	0·963	1·016	12 0	18 5	18 8	....	17 17¼	One rivet sheared	19 2	....

PROCEEDINGS.

GENERAL MEETING, SATURDAY, FEB. 3, 1872, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

E. F. BOYD, Esq., President of the Institute, in the Chair.

The Secretary read the minutes of the previous meeting and also the minutes of the Council.

The following gentlemen were then elected :—

Honorary Member—

The Very Rev. The Dean of Durham.

Members—

Mr. J. E. Pearson, Golborne Park, near Newton-le-Willows.
Mr. John Moody, Bengal Coal Company, Raneegunj, Bengal.
Mr. Arthur Woodgate, Chemical Manure Manufacturer, Newcastle.
Mr. H. H. Wake, C.E., River Wear Commissioners, Sunderland.

Students—

Mr. Addison Molyneux Potter, Heaton Hall, Newcastle.
Mr. Daniel Gilmour, Towneley Colliery, Blaydon-on-Tyne.

The following were nominated for election at the March meeting :—

Members—

Mr. John B. Eminson, Londonderry Offices, Seaham Harbour.
Mr. Thomas Clarke, South Benwell Colliery, Newcastle.
Mr. Andrew Farmer, Westbrook, Darlington.
Mr. Arnold Thomas, M.E., Bilson House, near Newnham, Gloucestershire.
Mr. George H. Haswell, Mechanical Engineer, 11, South Preston Terrace, North Shields.
Mr. William Heppell, Brancepeth Colliery, Willington, County of Durham.

Students—

Mr. Oswald Dyson, 1, Rye Hill Street, Newcastle.
Mr. William Moses, Lumley Colliery, Fence Houses.
Mr. Ernest Hague, Towneley Colliery, Blaydon-on-Tyne.

The President remarked, that it had been suggested to the Council that it would be advisable to have the Institute enrolled under the Limited Liability Act, certain clauses in which enabled members of scientific societies to enrol themselves without having the word "limited" attached. Under these circumstances it had been deemed advisable to consult their solicitor, Mr. Dees, who had requested further time to make the necessary inquiries. Mr. Cochrane and Mr. Newall have been kind enough to offer to make the necessary inquiries and report again to the Council.

Mr. W. N. Taylor then read a paper on "A Description of Air-Compressing Machinery as applied to Underground Haulage, etc., etc., at Ryhope Colliery."

DESCRIPTION OF AIR-COMPRESSING MACHINERY AS APPLIED TO UNDERGROUND HAULAGE, ETC., AT RYHOPE COLLIERY.

By Mr. W. N. TAYLOR.

No doubt it has been more or less familiar to the members of this Institute, that the application of compressed air as a hauling power, and in the ventilation of the mine, has been recently on trial in Ryhope Colliery.

Before commencing to read this paper in detail, the author may be permitted to remark that the original intention was to place the 150 H.P. engine, now supplying compressed air in the Hutton seam, and so work all the Maudlin coals by drop staples or inclines to the Hutton seam, the roof of the latter being so much superior to that of the Maudlin, which is very bad indeed.

The time, however, required to make the necessary engine roads was found to be so long, and the cost of horses in the meantime so heavy, that it was determined to erect the 150 H.P. engine on the surface, and work the underground engines by compressed air from it; and this has accordingly been done.

The air compressing cylinders are two in number, made by the Grange Iron Company Limited, each 33 inches diameter and 5 feet length of stroke, which receive their motion from a pair of steam cylinders, each 32 inches diameter and 5 feet stroke, placed at the surface.

Plate No. XIV., Figure 1 is a longitudinal section of one air cylinder through the delivery and inlet valves.

Figure 2 is a half section of the end showing the delivery pipe, and a half elevation looking on the cover.

Figure 3 is a cross section through the cylinder.

Plate No. XV. shows a plan and elevation of the inlet and delivery valves, and Plate No. XVI. shows a plan and elevation of the cylinders. Both the cylinders with their covers are jacketted, and a strong circulation of water is kept running all round them; this water is admitted at the sides and runs out at the pipes A A, which rise up about 3 feet above the tops of the cylinders. The inlet valves B B, and the outlet valves C C, are each 8 inches diameter, and are provided with small pistons P P, Plate XV., working in cylinders Q Q, with India-rubber stops R R, to prevent noise and cushion the blow when the valves are opening and closing. D D, Plate XVI., are inlet valves $1\frac{1}{2}$ inch diameter, with regulating screws, connected by pipes with the bottom of the receiver, which contains a few gallons of oil, a portion of which, sufficient to fill up the waste spaces at the ends and also to lubricate the pistons and valves, is admitted every stroke, and is delivered again in to the receiver with the compressed air through the pipes E E, each 8 inches diameter.

The receiver at bank is 30 feet long, and 6 feet diameter, and three-eighths of an inch thick, fitted with two safety-valves, each 3 and 4 inches in diameter. The two delivery pipes join the receiver on the side, and the air is taken down the pit by 9 inch pipes hereafter described.

The steam engine, Plate No. XVII., made by Messrs. T. Murray and Co., consists of two cylinders, each 32 inches diameter, length of stroke 5 feet. The connecting-rods are connected to wrought iron cranks keyed on to a wrought iron shaft 18 inches diameter, on which is placed a massive fly-wheel 22 feet diameter, weighing 14 tons.

The air cylinders work direct from the piston-rods of the steam cylinders. Both the piston rods of the air and steam cylinders are connected to wrought iron cross-heads with loose boxes on the ends of the piston-rods of the air cylinders, so as to allow the working of one cylinder only when necessary.

The air is taken from the air cylinders in pipes to No. 1 receiver at bank. The receiver is, as stated before, 30 feet long and 6 feet diameter, and three-eighths of an inch thick, fitted with two safety-valves 3 and 4 inches diameter, and loaded at 40 lbs. on the square inch.

The air is taken from No. 1 receiver at bank to No. 2 receiver at the bottom of shaft, a distance of 518 yards (Plate No. XVIII.), in malleable iron pipes, 9 inches diameter inside, three-eighths of an inch thick, and 12 feet long, manufactured by the Imperial Patent Tube Company, of Birmingham; the flanges are three-quarters of an inch thick, welded on and properly turned and faced, and secured together by 8 three-quarter inch bolts; the faces of the joints are plain, and made with copper wire gauze and patent cement, and the joints tested to 3000 lbs. on the square inch.

No. 2 receiver at the bottom of shaft is 12 feet long, and 4 feet diameter, and three-eighths of an inch thick, and is fitted with one safety-valve, 3 inches diameter, loaded at 50 lbs. on the square inch.

The air is taken from No. 2 receiver to No. 3 receiver, which is of the same size, at the top of the South Steam Engine bank, a distance of 101 yards, in metal pipes, 8 inches diameter, and five-eighths of an inch thick. The joints are secured with 8 three-quarter inch bolts, and are so turned and faced as to receive India rubber washers made the proper thickness, while the metal is face to face.

From No. 3 receiver the air is taken with 8 inch pipes a distance of 57 yards to the bottom of the engine bank to a stop valve; the pipe from the stop valve to No. 4 receiver, a distance of 804 yards, is 6 inches diameter, with two $1\frac{1}{4}$ inch bolts in each flange, jointed as before described.

The air is taken from No. 4 receiver to a double hauling engine with cylinders 14 inches diameter by 18 inches stroke, Plate No. XIX. (made by Messrs. John Fowler and Co., of Leeds); the rope drums are on the second motion, with spur gear $2\frac{1}{4}$ to 1; the main rope drum is 4 feet diameter, with a steel rope five-eighths of an inch diameter; and the tail drum is 4 feet 6 inches diameter, with a steel rope half an inch diameter. The distance from No. 4 receiver to the engine hole is 25 yards, making the distance from No. 1 receiver at bank to the underground engine a distance of 1505 yards. The bends and turns in all the pipes from the surface to the engine are made of as large a radius as possible, and larger in diameter than the inside diameter of the straight pipes, so as to cause the friction to be reduced as much as possible. This engine hauls the set, consisting of 30 tubs, each containing 18 cwts., from a distance of 1300 yards, in 7 minutes. The gradients of this plane are shown on Plate No. XX.

The piston rods are taken through the back ends of the cylinders, and the engines are fitted with the common slide valve; great care has been taken to have the exhaust passage as large as possible, so as to avoid ice being formed therein; the engine exhausts both out of the top and bottom of the slide chest; glycerine is used to lubricate the pistons and slides, and also to prevent the formation of ice. Plate No. XXI. is a section of the cylinder of the hauling engine, showing the exhaust passage A A arranged for the air to discharge itself, both at top and bottom; with this exception, the cylinder is similar to that of an ordinary steam engine.

The foregoing descriptions and plans will show the precise nature of the power employed, and the mode of its application; but what has more especially to be dealt with at present, is the result obtained.

As already observed, the engine on the surface has two horizontal cylinders, 32 inches in diameter, representing a nominal horse power of 150 horses.

Diagrams showing the results obtained are given in Plate No. XXII., and a description of each diagram for the various engines now follows.

Only one 33-inch air cylinder driven by the two 32-inch engines is now employed to drive the underground engine, which consists of two cylinders each, 14 inches diameter, as already mentioned.

No. 1 *Diagram.*

Front end of right-hand engine, No. of revolutions per minute 12 ... ... Average pressure per square inch, 13·77 lbs.	H.P. =	40·28.

No. 2 *Diagram.*

Back end of right-hand engine, No. of revolutions per minute 12 ... ... Average pressure per square inch, 16·5 lbs.	H.P. =	48·25.
		2)88·53.
Average H.P. for one engine		44·26.

No. 3 *Diagram.*

Front end of left-hand engine, No. of revolutions per minute 18 ... ... Average pressure per square inch, 2·07 lbs.	H.P. =	9·102.

No. 4 *Diagram.*

Back end of left-hand engine, No. of revolutions per minute 18 ... ... Average pressure per square inch, 3·05 lbs.	H.P. =	11·186.
		2)20·288.
Average H.P. for one engine		10·144.

No. 5 *Diagram.*

Back end of air compressor, No. of revolutions per minute 12 ... ... Average pressure per square inch, 17·87 lbs.	H.P. =	55·574.

No. 6 *Diagram.*

Front end of air compressor, No. of revolutions per minute 12 ... ... Average pressure per square inch, 18·4 lbs.	H.P. =	57·226.
		2)112·800.
Average H.P. for one compressor		56·400.

No' 7 *Diagram.*

Back end of air compressor, No. of revolutions per minute 12 ... ... Average pressure per square inch, 23·9 lbs.	H.P. =	74·51.

No. 8 *Diagram.*

Front end of air compressor, No. of revolutions per minute 12 ... ... Average pressure per square inch, 25·0 lbs.	H.P. =	77·74.
		2)152·25.
Average H.P. for one compressor		76·125.

No. 9 *Diagram.*

Interior engines ... ...
Left-hand engine, back end ... ...
30 empty tubs going in to far end .. ..
Air-pressure by gauge, 40 lbs. ... ...
No. of revolutions per minute, 94 ... ...
Average pressure per square inch, 10·45 lbs ... ...

H.P. = 13·745.

No. 10 *Diagram.*

Left-hand engine, back end ... ...
24 full tubs from first branch ... ...
Air-pressure by gauge, 40 lbs. ... ...
No. of revolutions per minute, 70 ... ...
Average pressure per square inch, 14·5 ... ...

H.P. = 14·13.

No. 11 *Diagram.*

Left-hand engine, back end ... ...
30 empty tubs going into farthest branch ... ...
Air-pressure by gauge, 39 lbs. ... ...
No. of revolutions per minute, 90 ... ...
Average pressure per square inch, 15·135 ... ...

H.P. = 19·018.

No. 12 *Diagram.*

Left-hand engine, back end ... ...
25 empty tubs going into first branch ... ...
Air pressure by gauge, 42 lbs. ... ...
No. of revolutions per minute, 100 ... ...
Average pressure per square inch, 16·725 ... ...

H.P. = 23·370.

No. 13 *Diagram.*

Left-hand engine, back end ... ...
30 full tubs from far end ... ...
Air-pressure by gauge, 35 lbs. ... ...
No. of revolutions per minute, 75 ... ...
Average pressure per square inch, 28·3 ... ...

H.P. = 29·702.

No. 14 *Diagram.*

Left-hand engine, front end ... ...
30 full tubs from far end ... ...
Heaviest grad., $\frac{7}{8}''$ per yard ... ...
Air-pressure by gauge, 33 lbs. ... ...
No. of revolutions per minute, 70 ... ...
Average pressure per square inch, 22·6 ... ...

H.P. = 22·13.

No. 15 *Diagram.*

Left-hand engine, front end ... ...
30 full tubs from far end ... ...
Lighter part of bank ... ...
Air-pressure by gauge, 42 lbs. ... ...
No. of revolutions per minute, 70 ... ...
Average pressure per square inch, 17·4 ... ...

H.P. = 17·04.

No. 16 *Diagram.*

Left-hand engine, front end	H.P. = 23·84.
30 empty tubs going in	
Air-pressure by gauge, 40 lbs.	
No. of revolutions per minute, 120	
Average pressure per square inch, 14·2	

Steam cylinder, 32 inches diameter; stroke, 5 feet; air-compressor, 33 inches diameter, 5 feet stroke; interior hauling-engine cylinder, 14 inches diameter, stroke, 1 foot 6 inches.

EXPERIMENTS WITH COMPRESSED AIR FOR WORKING UNDERGROUND HAULING ENGINE.

Time of Measurement.	Number of Strokes of Steam Engine at Bank.	Bank Steam Pressure.	Bank Air Pressure.	Temperature of Air at Outlet.	Temperature of Air in the Outlet Pipe, 6 ft. 10 in. from Cylinder.	Temperature of Air at No. 1 Receiver, bottom of the Pit.	Pressure of Air at No. 1 Receiver.	Temperature of Air in No. 2 Receiver, top of the Engine Bank.	Temperature of Air at Air Engine, Inbye Receiver.	Pressure of Air at Engine.	Remarks.
A.M.		Lbs.	Lbs.				Lbs.				
10·15	14	15	40	216	236	75	46	66	58	45	Engine standing.
10·20	14	15	41	214	234	75	46	66	58	39	Engine running empty set inbye.
10·25	14	16	39	216	236	74	44	66	58	40½	
10·30	16	17	42	216	236	74	46	66	58	41½	
10·35	14	17	33	208	228	75	47	66	58	35	Engine running full set outbye fr. No. 4 landing.
10·40	14	18	34	206	226	74	35	66	58	30	

The general result of the indications is, that whilst the steam engine is working at a net power of 78·4 horse-power, the underground hauling engine is working at 51·8 horse-power.

It will appear from the foregoing, that the results obtained have been highly satisfactory; 40 horses have been dispensed with, and the Company have made arrangements for erecting another engine of similar size in the mine, which will lay off from 30 to 40 additional horses; and should success follow, they propose erecting as many more engines as can be worked from the power at bank.

Among other advantages resulting from the use of compressed air for underground engines, may be stated the following:—

1st.—It is obviously of great importance to have a large power which can be applied for any purpose and at any moment, to any part of the mine.

2nd.—Possessing this power, it is a mere question of detail to use means for working the coal and bringing it to the point from which it is to be led by the air engine, thus dispensing, in a great measure, with manual labour, both as regards hewing and putting the coals. Small locomotive compressed air engines might be used for conveying the coals from the hewer to the engine landing.

3rd.—Compressed air, at a pressure of 40 lbs., has already been successfully tried at Ryhope Colliery, in airing a stone drift. It is carried in by a 1-inch diameter iron pipe, which, say at 30 lbs., would give about 115 cubic feet per minute.

This drift is 246 yards from the pit, and is driven about 200 yards, rising $2\frac{1}{2}$ inches per yard.

Before the introduction of compressed air, the temperature in the stone drift was high, and consequently the men could not work so vigorously as they would have done in a lower temperature.

Now, however, the change is very considerable. The air-pipe, an inch in diameter, is taken away from the receiver at the bottom of the pit into the drift, and the air, issuing from the pipe at a pressure of 40 lbs. to the inch, instantly clears the drift from any powder, smoke, or gas, and being, of course, of low temperature, it has very materially reduced the heat in the drift, the men stating that they can do much more work than before.

4th.—Assuming, as we have already done, that these air-engines are generally employed in mines, it will readily appear, that a most powerful agent is available at any time for freeing any working place from gas of any description, the only means required being to take a proper length of hose-pipe from the receiver to the part required to be freed from gas. The effect is instantaneous.

5th.—It having been shown and proved what the effect is in clearing a stone drift from gas, the next question would be, whether the compressed air might not be applied to the return air courses.

Assume, for instance, that there is a large goaf, which can only be cleared from gas around its edges by the present mode of ventilation, the question is what effect would follow in the goaf, if its contents were exhausted by forcing air at 40 lbs. per inch into the returns?

The effect, no doubt, would be very much greater than under present circumstances. This, however, is only referred to, to direct to it the attention of the members of the Institute.

6th.—It is anticipated that proportionately favourable results will follow the erection of three or more underground engines, which, it is expected, can be driven by the power at bank.

7th.—Many attempts have been made to work coal by machinery, and possibly failures have arisen from not having the motive power in a cheap, uniform, and compact shape. There can be no difficulty in these respects with regard to compressed air.

8th.—Among other advantages from using compressed air, one more especially important in deep mines is its tendency to reduce the generally high temperature, and there can be little doubt, that the deep mines of Great Britain will hereafter be worked chiefly through the application of compressed air, the exhaustion of which into the workings tends materially to reduce the temperature.

The exhaust air discharged from the one pair of hauling engines now at work, assuming 120 strokes per minute at a pressure of about 30 lbs. per square inch, gives 2160 cubic feet of air per minute, issuing into the workings at a temperature of about 3 degrees below freezing point.

9th.—It is obviously important to have communication with the interior of the mine in the event of anything occurring, and air-pipes will at once be available for this purpose, either for the introduction of water or the application of mechanical power.

Upon the whole it will be perceived from the foregoing, that very highly beneficial results may fairly be expected from the use of the compressed air engine, and these results, so far as experience has hitherto shown, may be classed under the heads of:—

1.—Economy as regards its application to any part of the interior of the mine.

2.—Additional safety to the mine, inasmuch as there is a more direct communication with and control over all parts.

3.—Having a power so easy of application to any part of the mine, its use for all purposes, where labour is concerned, must necessarily follow.

The President remarked, that the author was entitled to the very best thanks of the members present, for the pains and trouble he had taken in arranging and carrying out experiments upon this most important subject, and bringing the results to the knowledge of the Institute. He would not invite much discussion at present, partly because Mr. Taylor considered that sufficient time had not elapsed to enable him to speak with certainty on some points, and partly because he was empowered by Mr. Taylor to invite members to inspect the machinery any day that might be previously fixed; the discussion, in his opinion, would become much more interesting after this inspection.

Mr. Lawrence, in answer to a question from Mr. Cochrane, stated that the 51 horse-power in-bye and the 78 horse-power at bank were arrived at by simultaneous diagrams, each party conducting the experiment being provided with a watch previously set to a common standard.

Mr. Southern inquired if Mr. Taylor had made any experiments in getting coal by means of compressed air?

Mr. Taylor replied, that it was seriously in contemplation to use compressed air in the Hutton seam, for the purpose of getting coal, and he had no doubt but that the arrangement would soon be carried out.

Mr. Boyd asked Mr. Taylor if any experiments had been made to ascertain how the loss of 27 horse-power in the transmission of the power from the original motion to the air engine could be accounted for, and what proportion of it was due to the increase of temperature in the cylinder, and from the friction in passing through the pipes? He thought it would be an interesting investigation to trace out and account for that loss.

Mr. Lawrence stated, that the temperatures had been taken, both when the air left the compressing cylinder and at several places in its passage, so that all loss from this source could be easily accounted for. The temperature at the compressing cylinder was 216°, with the pressure at 40 lbs. to the inch, and, strange to say, at a distance of six feet from the cylinder, this temperature was increased to 236°, and as there was no contraction of the pipe, or any sharp bend, this circumstance seemed to him unaccountable. It is true, two thermometers were used, and these might not have coincided. The exhaust left the cylinder of the hauling engine accompanied with ice, and the temperature, close to the cylinder, was three degrees below zero. He had not made any calculation of the quantity of air used by the hauling engine, but it usually went 120 revolutions per minute and cut off, after the piston had traversed three-fourths of its stroke. He would add, that the gross horse-power at bank was 88; 10 horse-power was lost by friction, and was deducted from the gross horse-power, leaving 78, and this result was an average of the trials made at the time.

Mr. S. B. Coxon said, that it would be a great advantage if the paper could be printed before the members availed themselves of Mr. Taylor's kind invitation to visit Ryhope. They might then prepare themselves to observe the points on which they wished information; and, even if this delayed their visit for a few weeks, it would have the advantage of giving Mr. Taylor additional time for obtaining more data.

Mr. Southern observed that the paper was one of very great interest, and that it came at a very opportune time. It offered very many interesting subjects for consideration, and not the least among them was the effect it was likely to have on the ventilation of the pits and the cost of working the coal. It was also very satisfactory that the system had been adopted by such an influential company and was in such able hands. This he felt was a guarantee that no pains would be spared to give the whole matter a thorough and impartial trial.

The PRESIDENT was sure that the meeting would join in a cordial vote of thanks to Mr. Taylor for his admirable paper, and for his polite invitation to Ryhope. He quite agreed with Mr. Southern's remarks, and considered these experiments an era in the profession, which might lead to very remarkable results, not only as regarded hauling, but also in the general question of economy of labour in other respects, and in the efficient ventilation of mines.

The PRESIDENT then stated that the meeting had been made special to consider the following alteration of Rule IV., which it was proposed should stand as follows :—

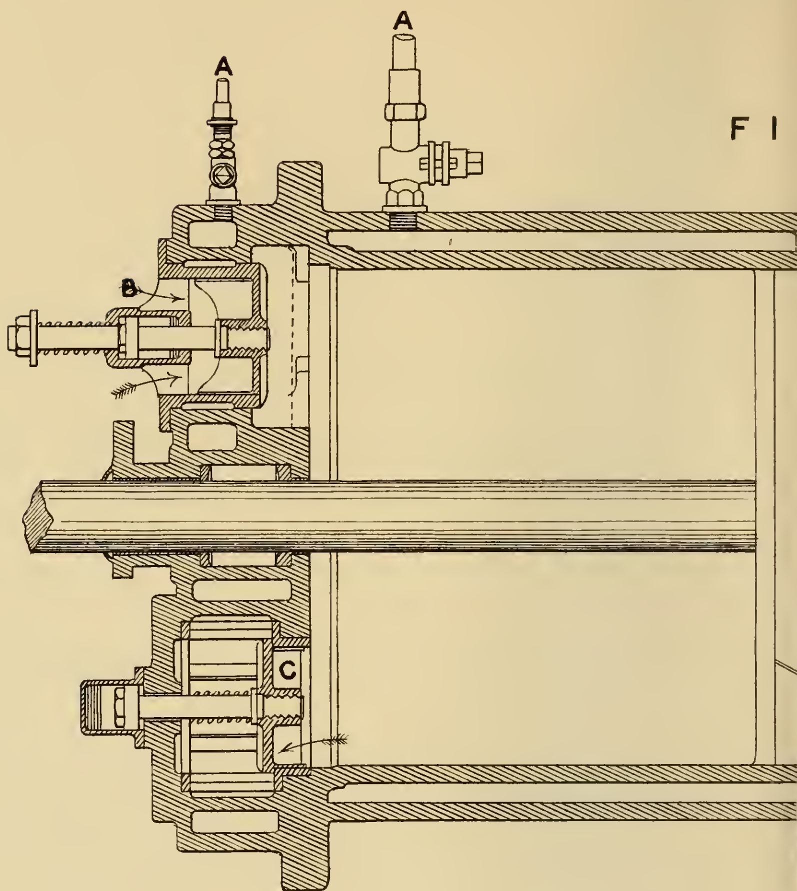
> "Honorary Members shall be persons who have distinguished themselves by their literary or scientific attainments, or who have made important communications to the Society, Government Mining Inspectors during the term of their office, and the Professors of the College of Physical Science, Newcastle-upon-Tyne, during their connection with the said College."

The alteration was unanimously agreed to.

The PRESIDENT then stated as this was probably the last time they would meet in this room, he would propose that they should pass a vote of thanks to the members of the Literary and Philosophical Society for their great kindness, courtesy, and liberality in allowing them the free use of their premises during the erection of their new offices, and also to the Librarian, who had been so incessantly alive to their interests and convenience. The Contractor had promised that the Wood Memorial Hall should be finished in a month; and it was suggested that, as soon as the necessary arrangements could be made, the hall should be formally opened, and advantage taken of the circumstance to invite members of other and kindred societies, whose kindness and hospitality had been extended to them on previous occasions.

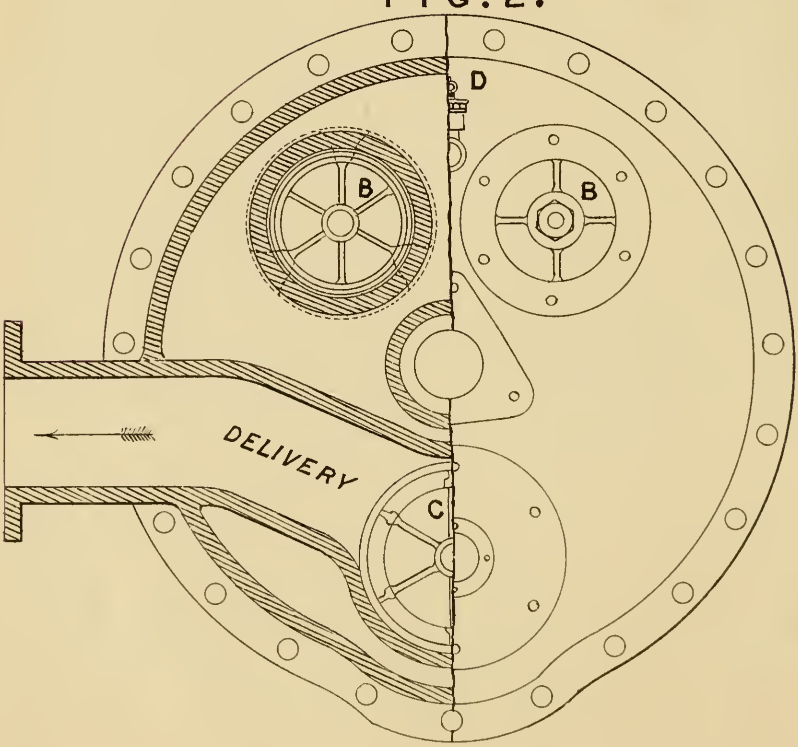
To illustrate Mr W. N. Taylor's Paper on Air

F I



SECTIONS OF THE AIR COMPRESSING
OF THE INLET AND OUTLET VALVE

FIG. 2.



Scale ¾

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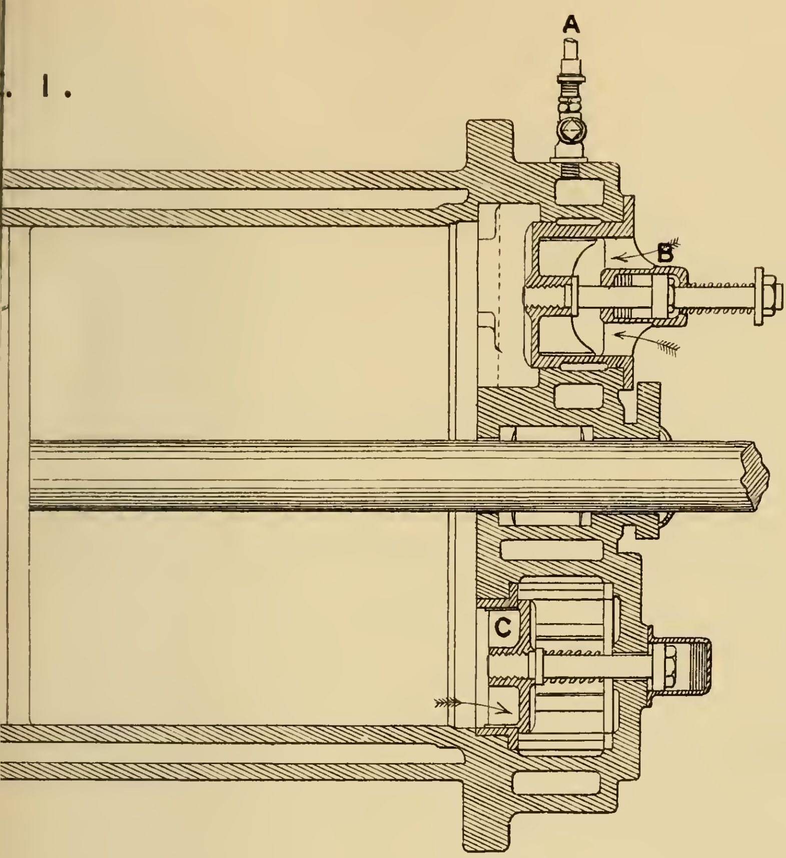
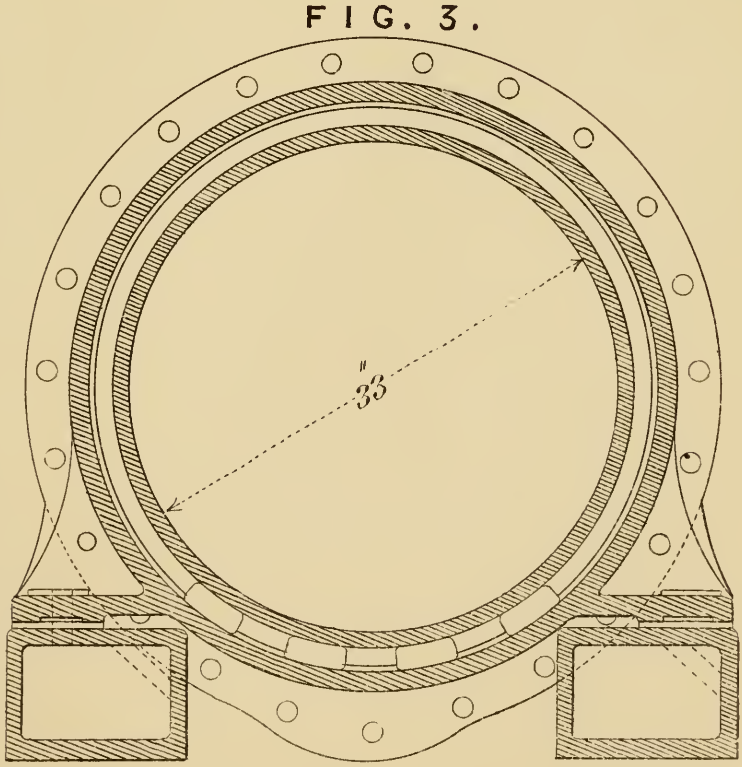


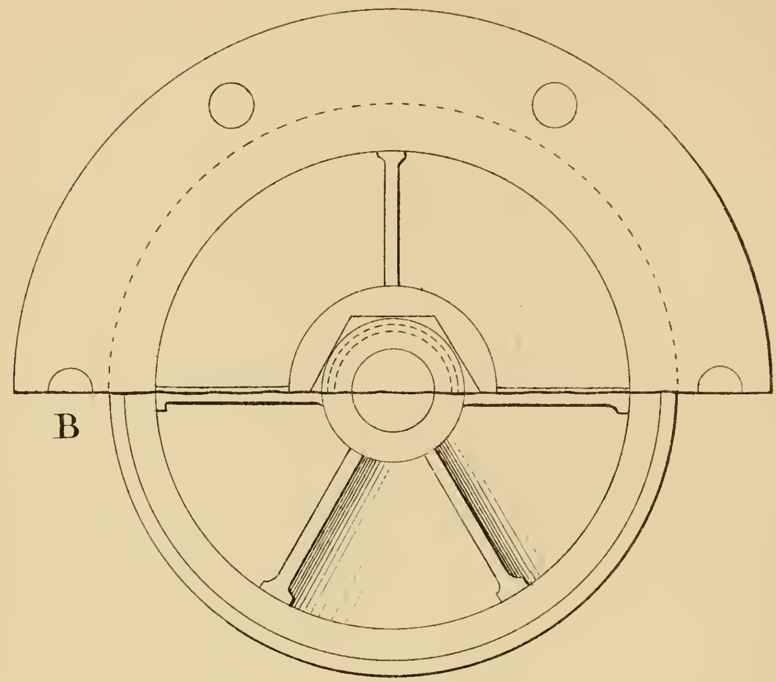
YLINDER, SHEWING THE POSITIONS

h = 1 foot.

FIG. 3.

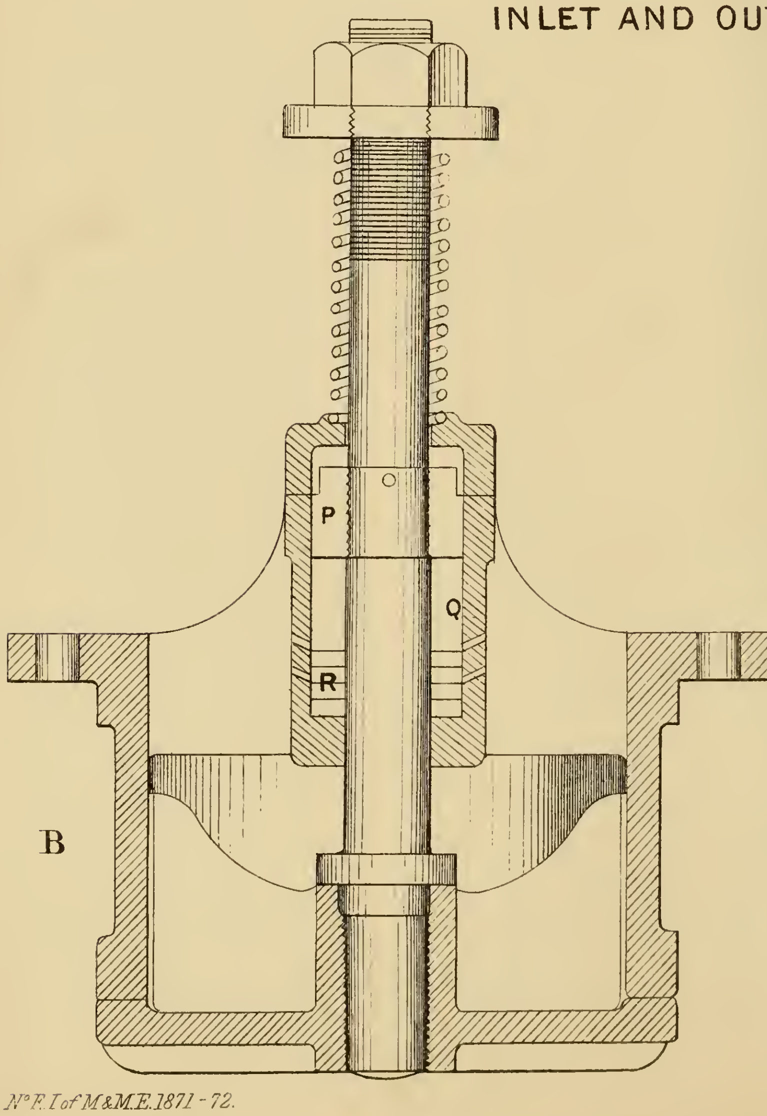


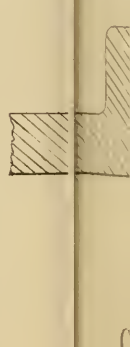
Andw Reid, Newcastle

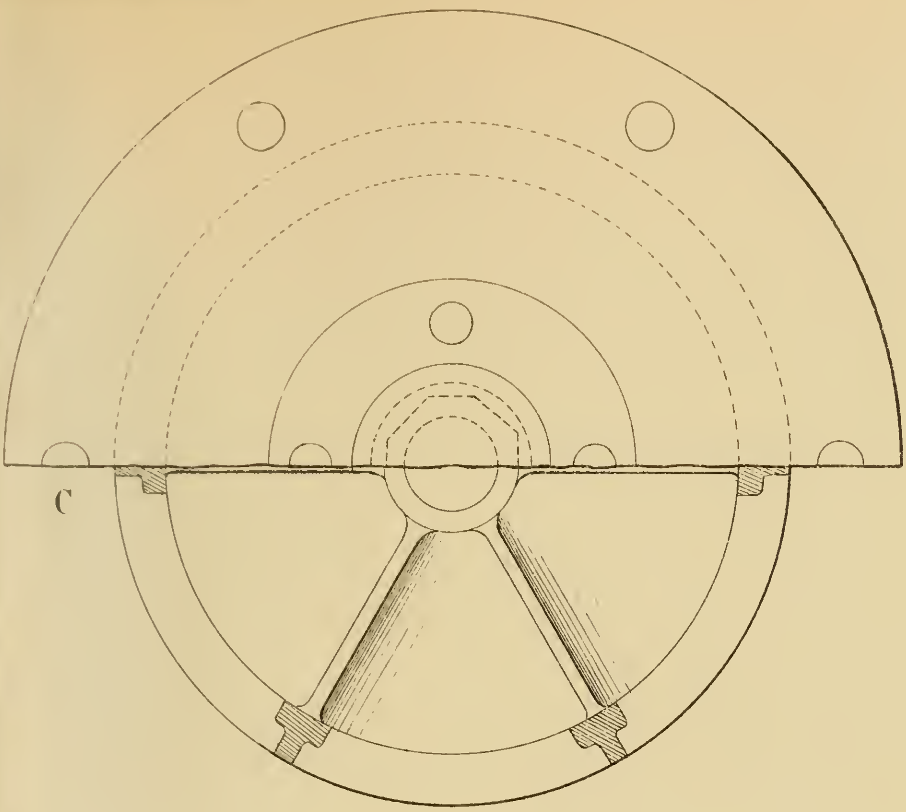


INLET AND OUTLET VALVES FOR OMP

Scale 3 inch =

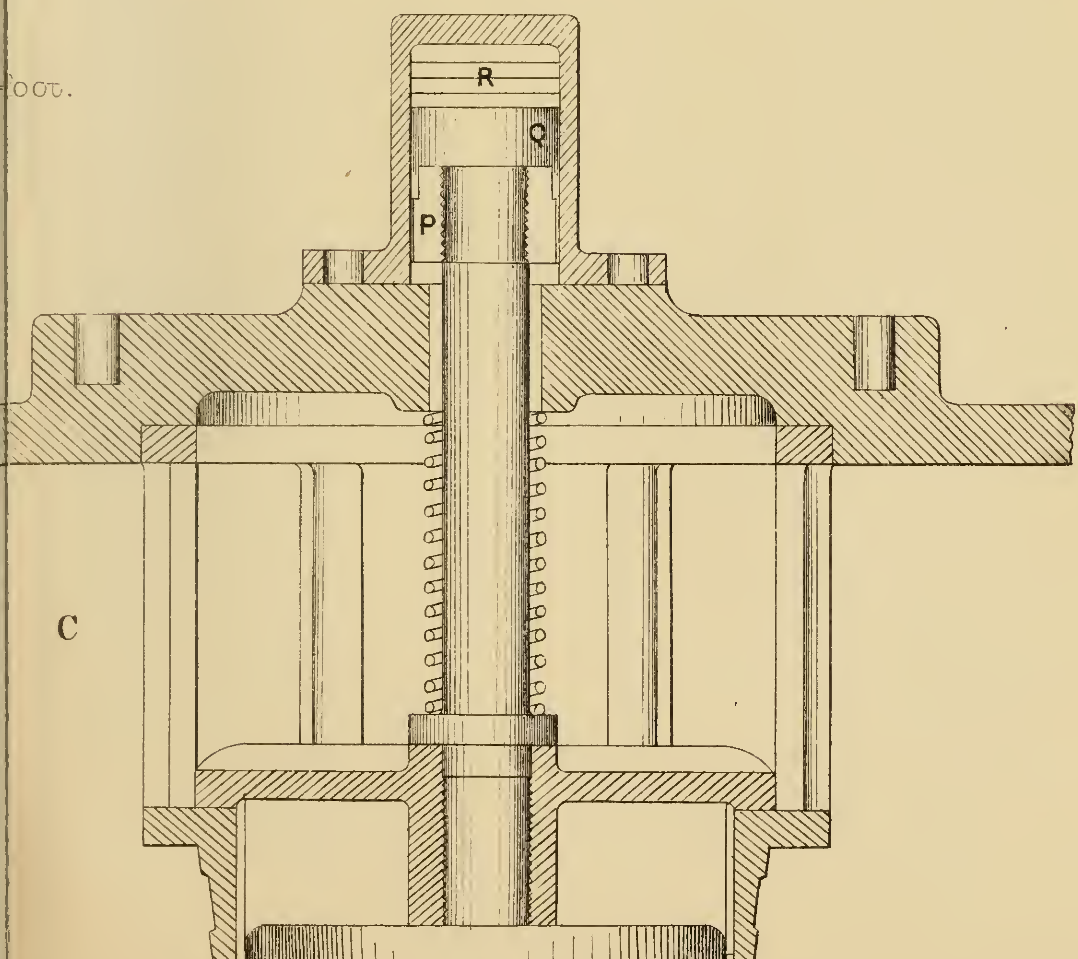






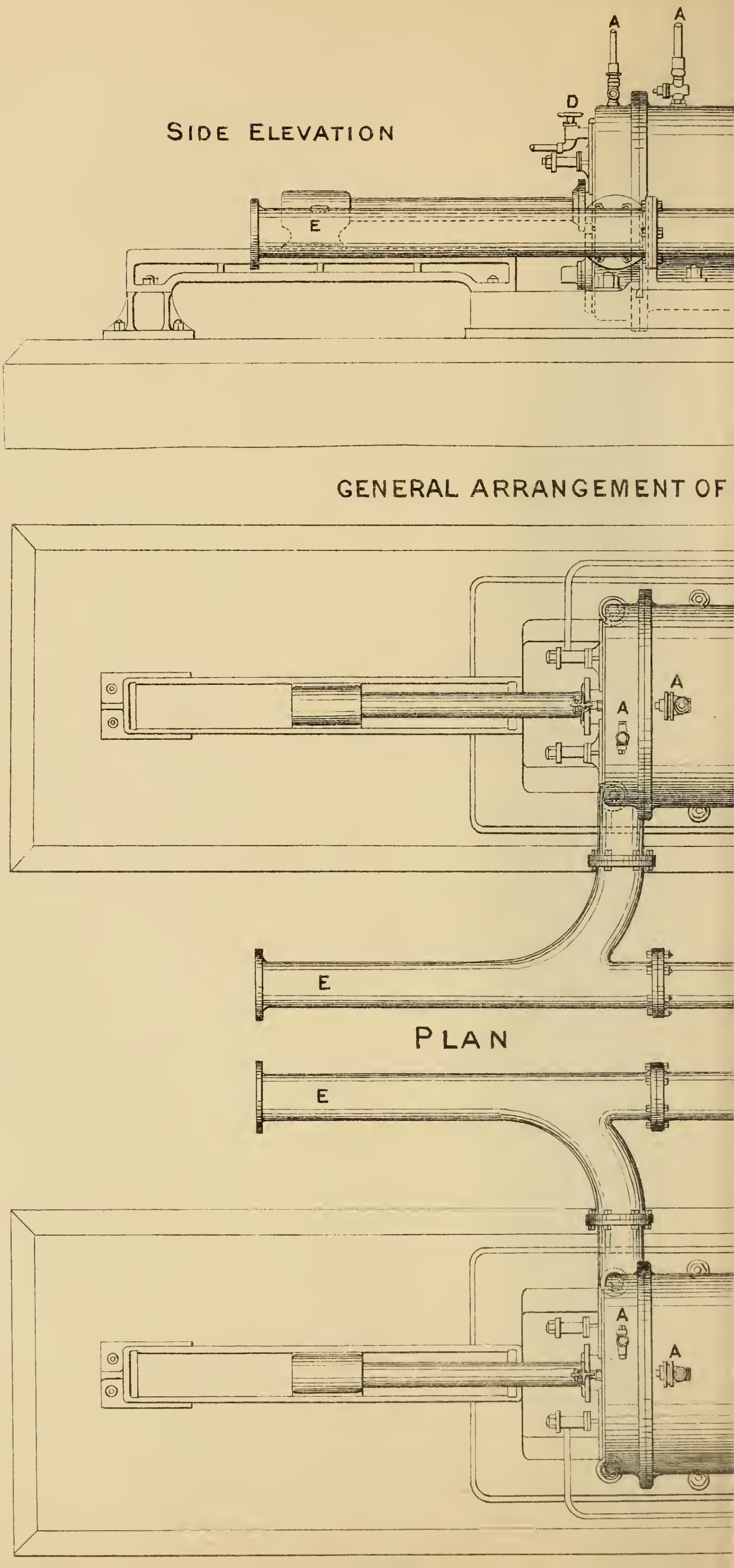
…MPRESSING CYLINDERS.

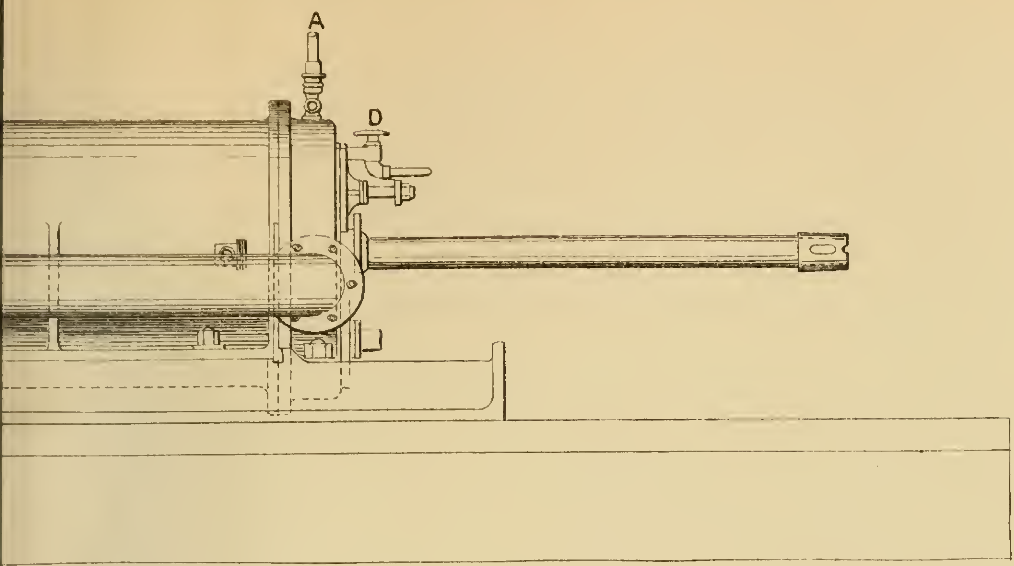
…=Foot.



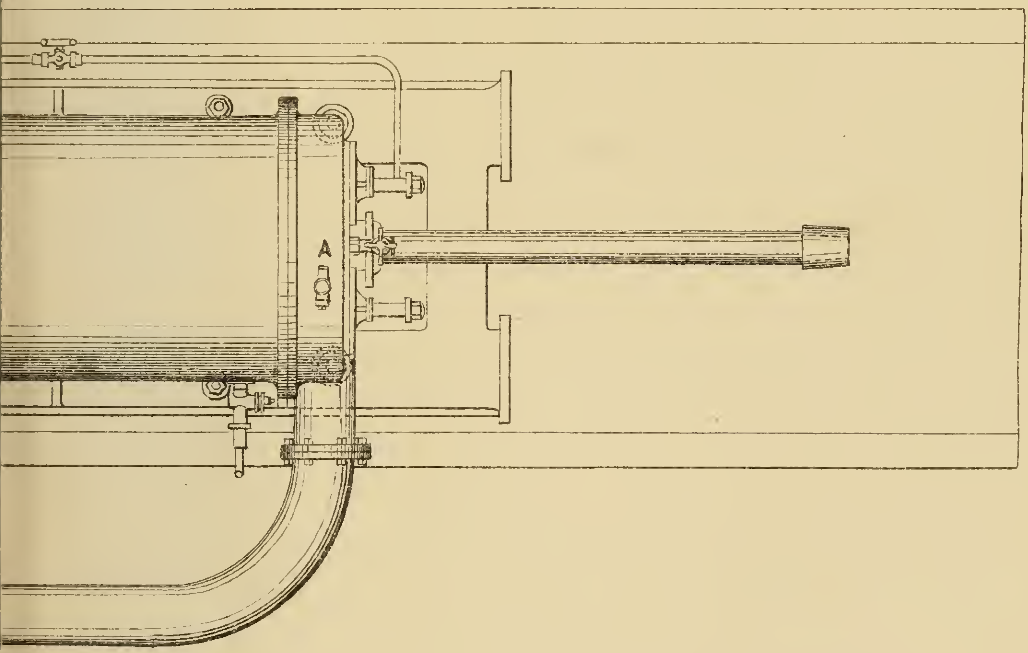
Andw Reid, Newcastle

To illustrate Mr. W. N. Taylor's Paper on

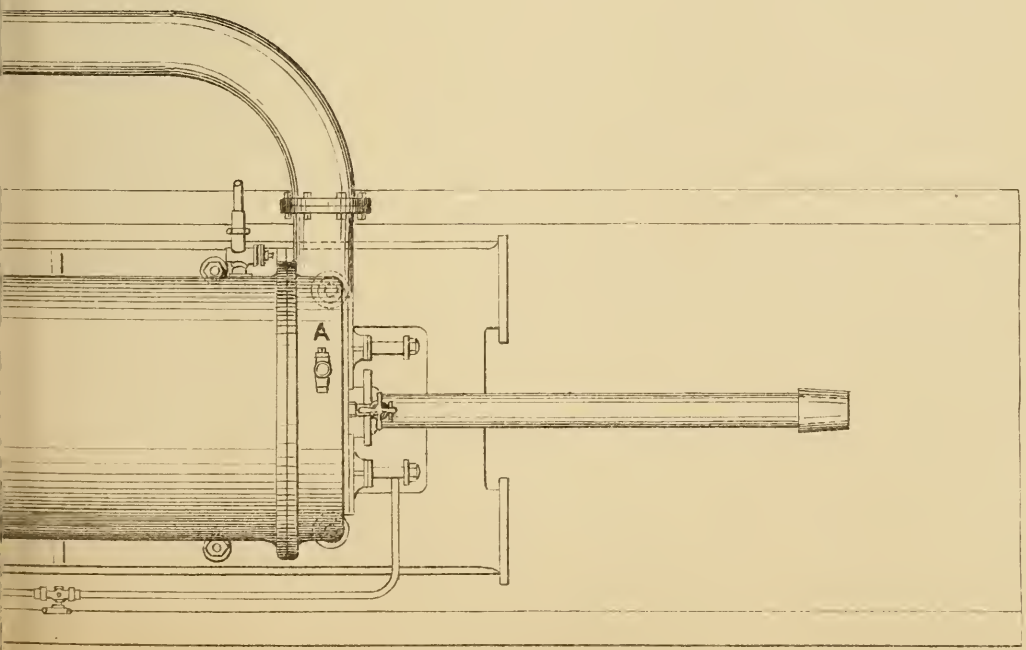




E AIR COMPRESSING CYLINDERS.

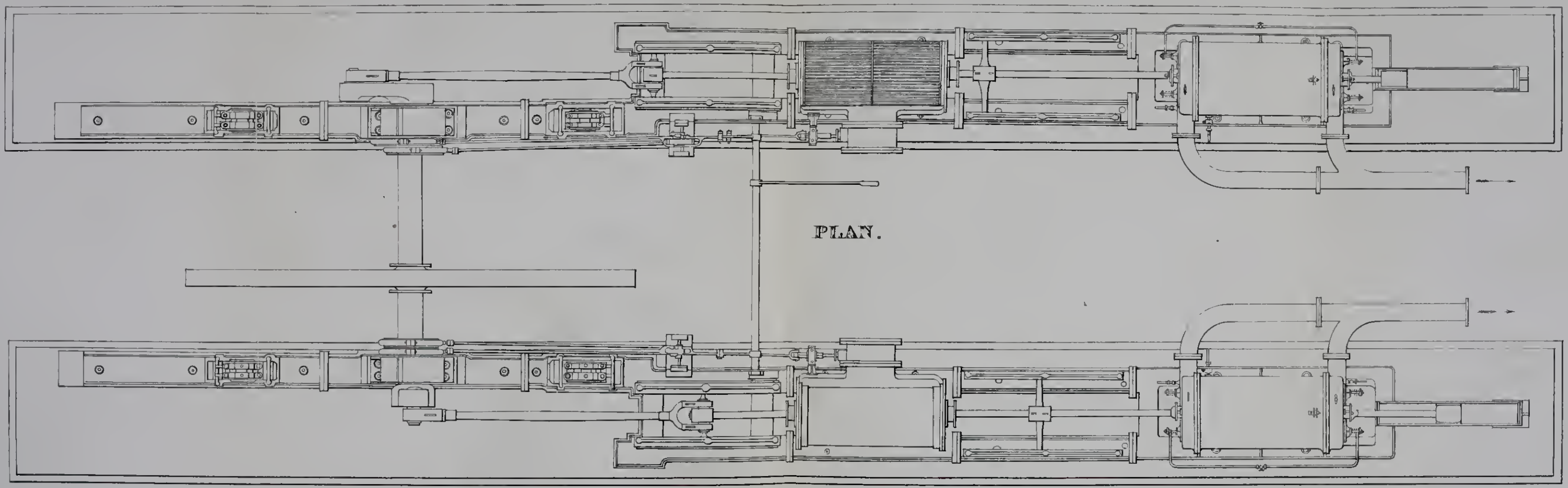


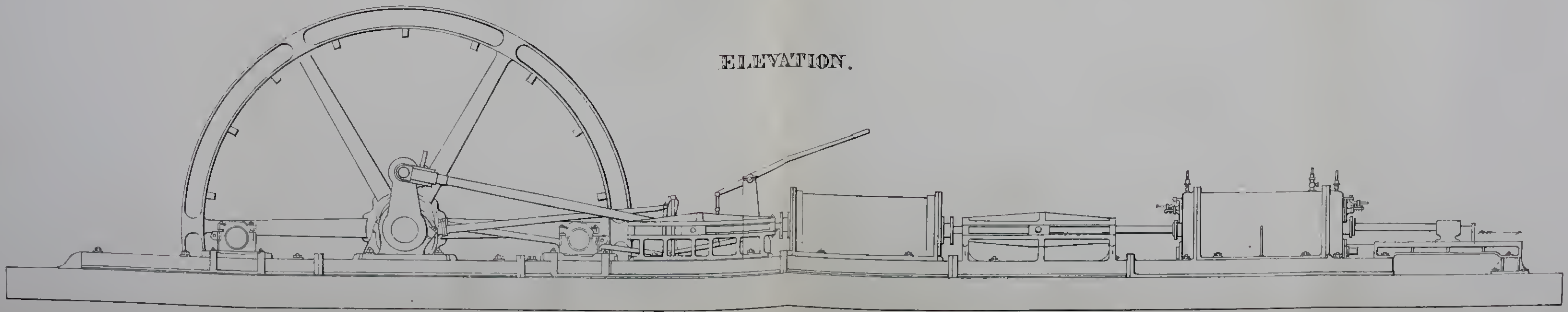
Scale $\frac{1}{3}$ inch = 1 foot.



And^w Reid Newcastle

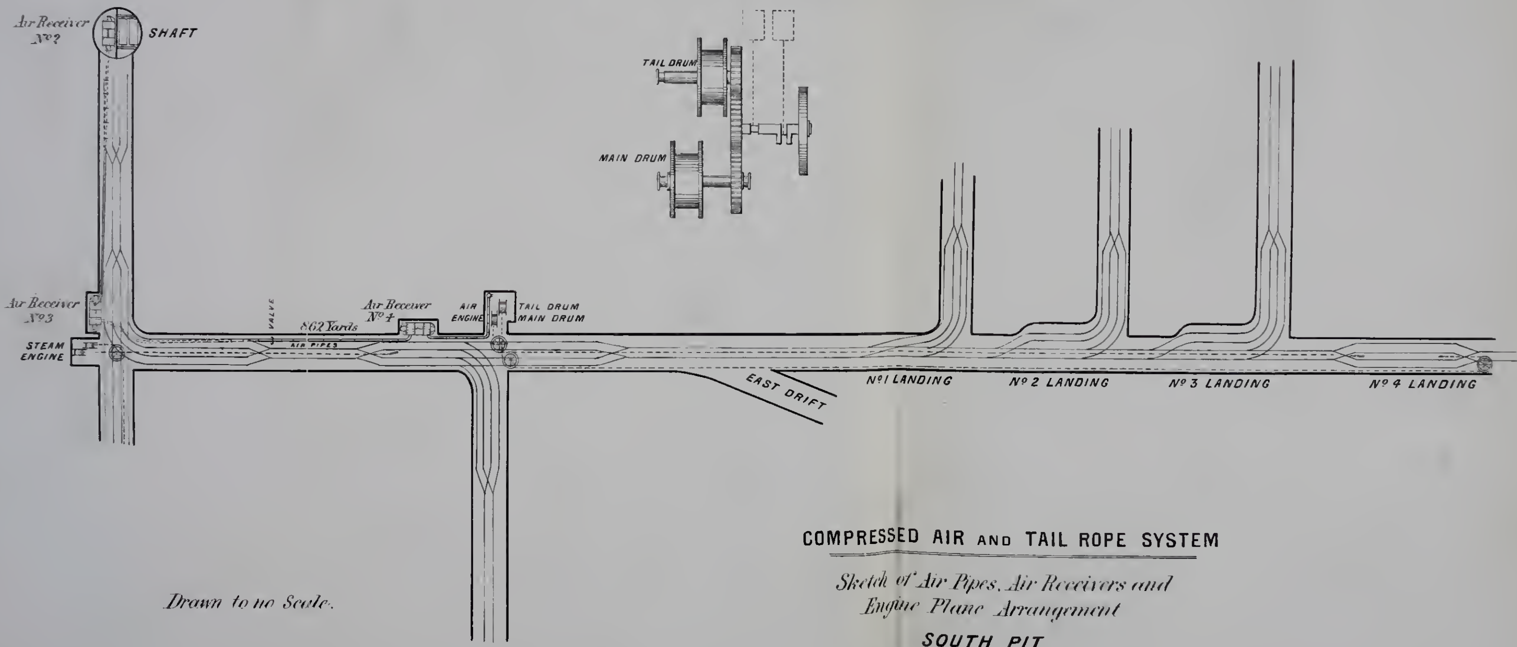
GENERAL ARRANGEMENT OF THE STEAM ENGINE AND AIR COMPRESSOR.





SCALE 3/16 IN. = 1 FOOT.

Sketch of Engine arrangement.



Drawn to no Scale.

COMPRESSED AIR AND TAIL ROPE SYSTEM

Sketch of Air Pipes, Air Receivers and Engine Plane Arrangement

SOUTH PIT

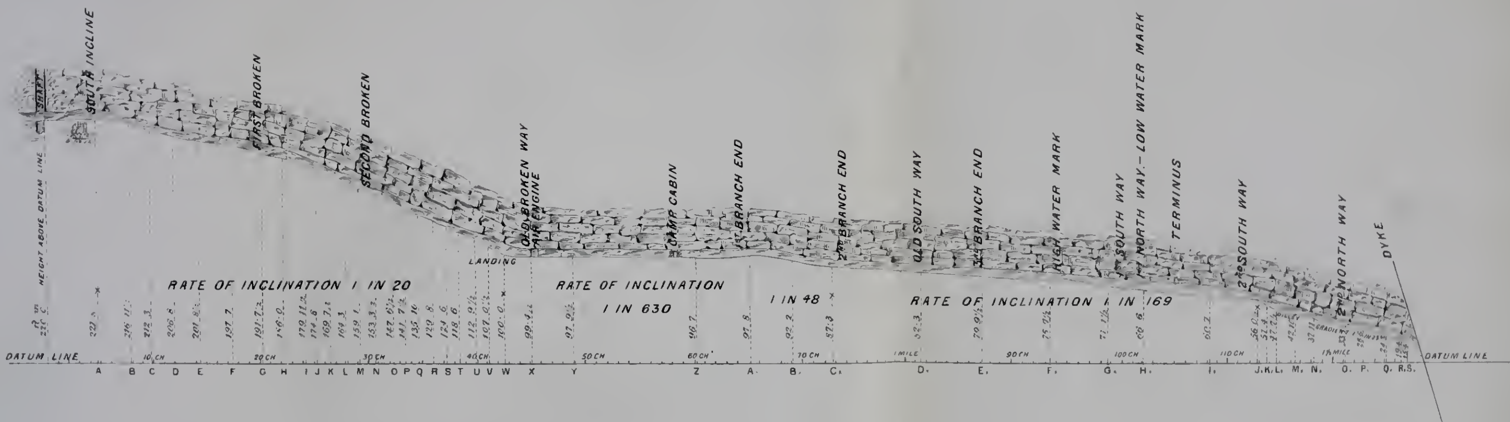
RYHOPE COLLIERY

SECTION OF LEVEL

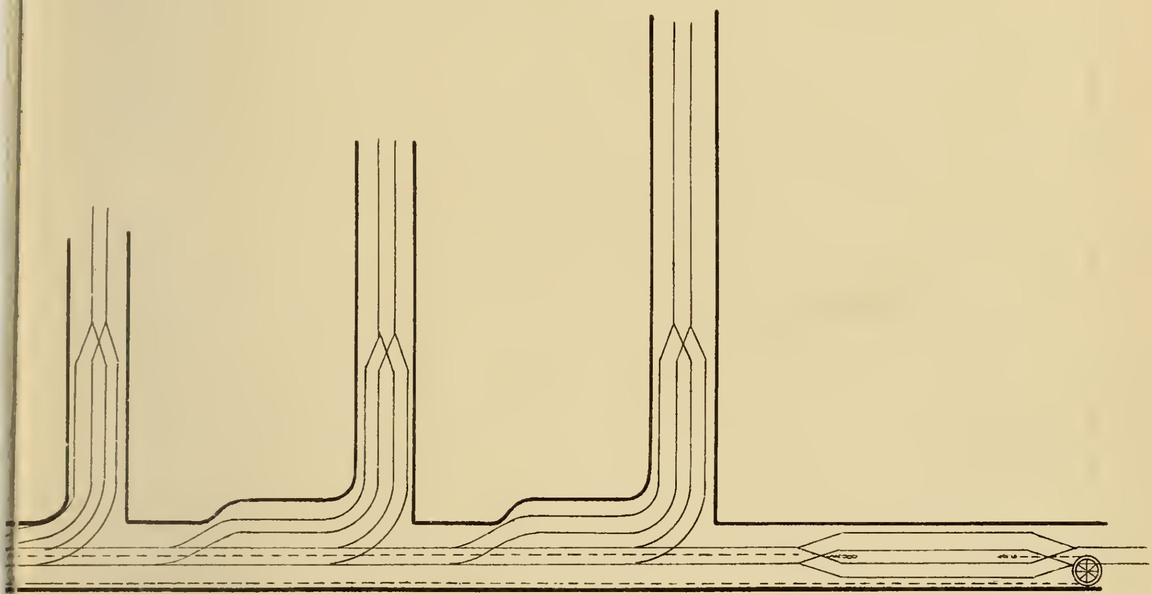
Taken from the South Pit, to the Face of the Dyke in

UNDER SEA COAL WORKINGS.

RYHOPE COLLIERY.



Horizontal Scale 12 Chains to an Inch.
Vertical Scale 120 Feet to an Inch.



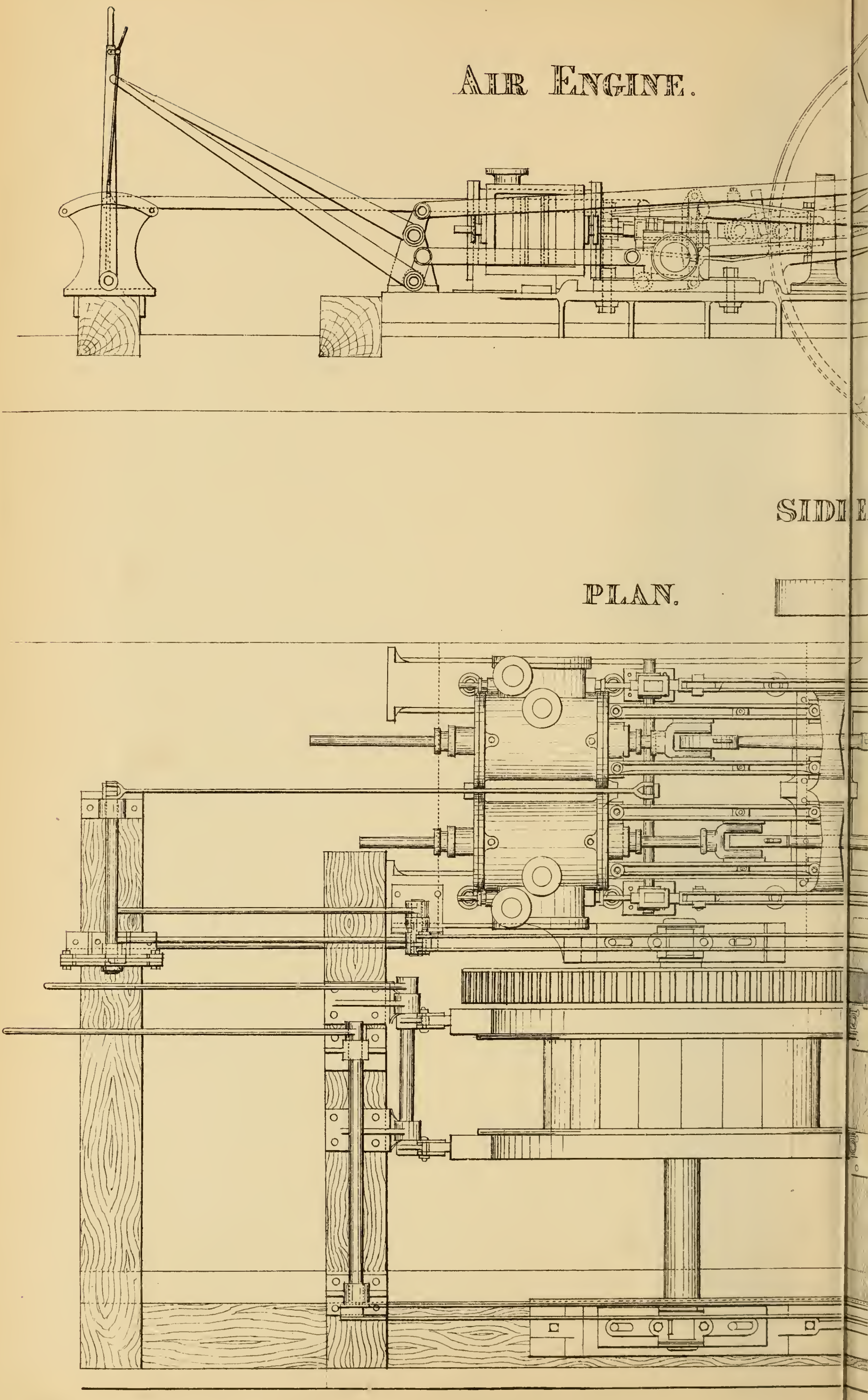
...D AIR AND TAIL ROPE SYSTEM

...f Air Pipes, Air Receivers and
...e Plane Arrangement

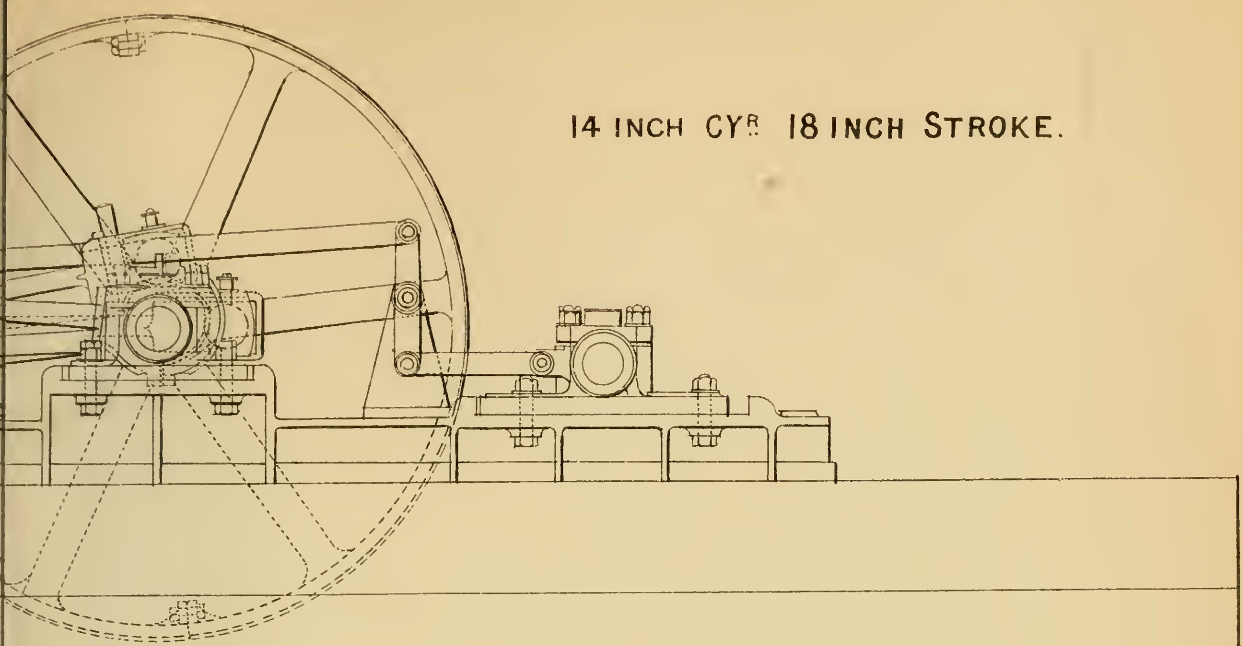
SOUTH PIT

...OPE COLLIERY

Andw Reid Newcastle

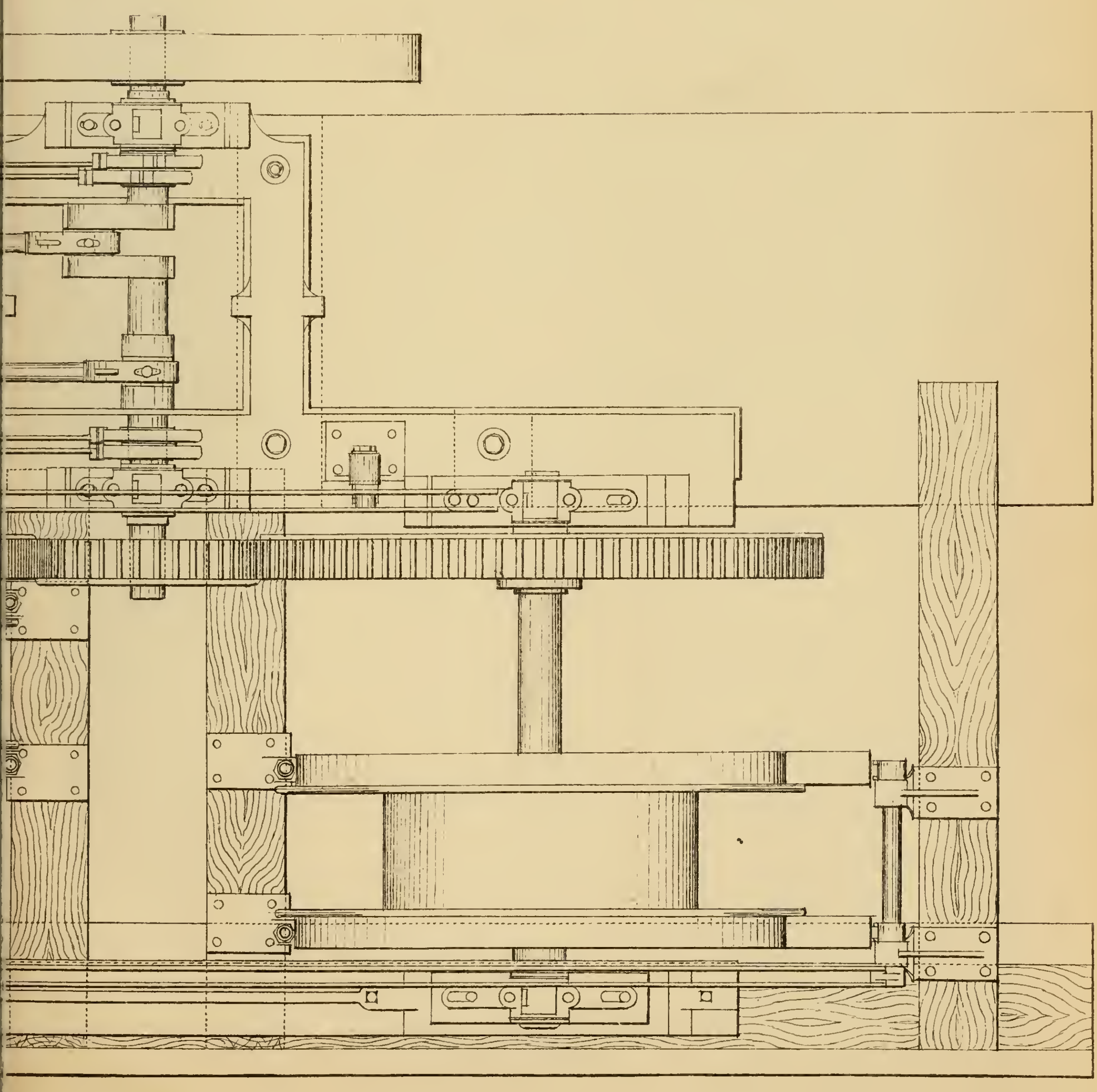

AIR ENGINE.
SIDE E
PLAN.

14 INCH CY^{R} 18 INCH STROKE.



ELEVATION.

SCALE $3/8^{THS}$ INCH = 1 FOOT.

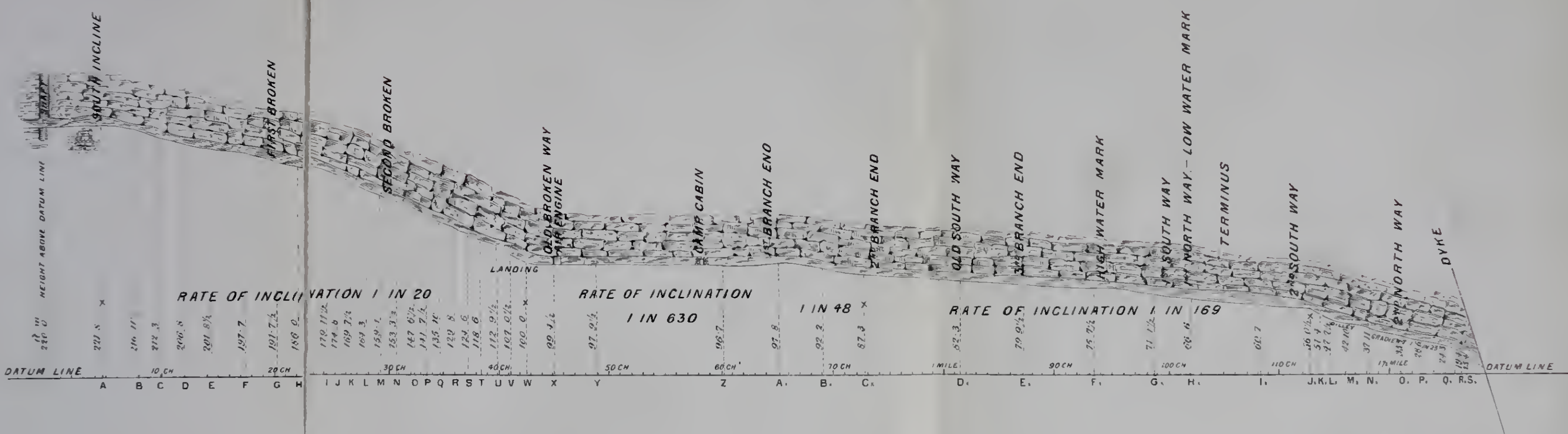


SECTION OF LEVEL

Taken from the South Pit, to the Face of the Dyke in

UNDER SEA COAL WORKINGS.

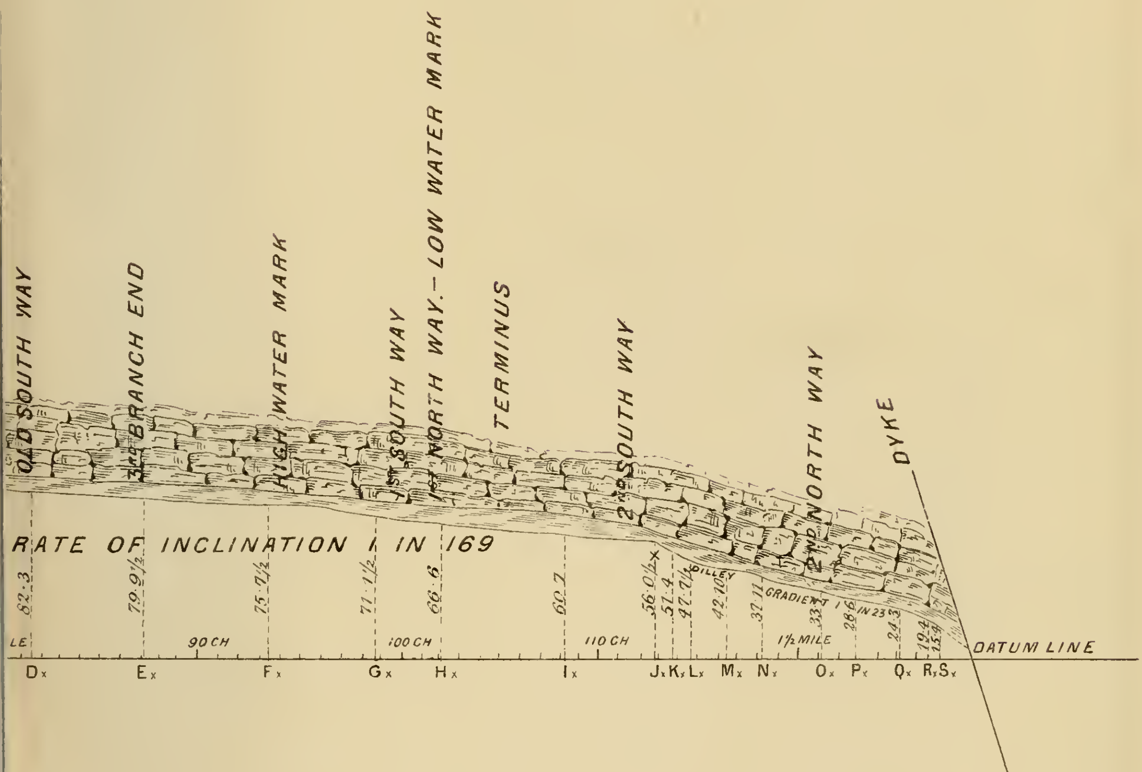
RYHOPE COLLIERY.



Horizontal Scale 12 Chains to an Inch.
Vertical Scale 120 Feet to an Inch.

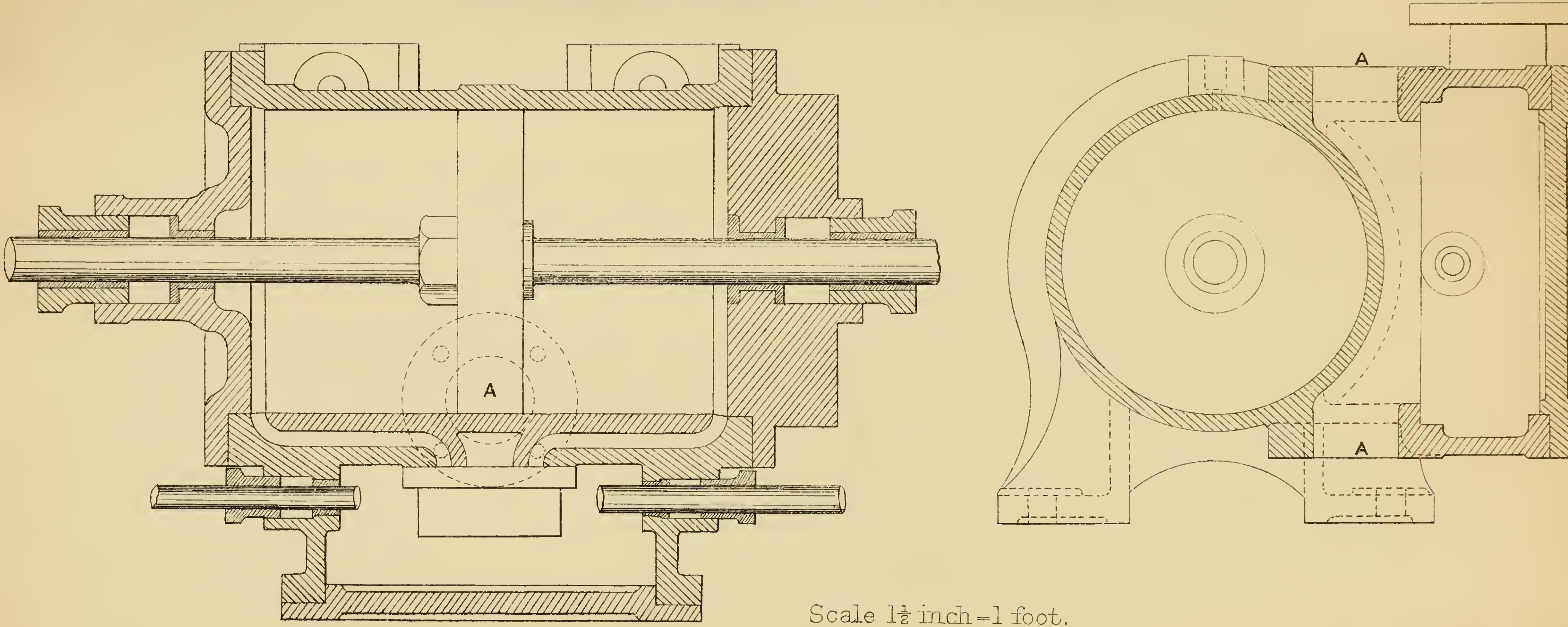
'the Dyke in

GS.



To illustrate Mr. W. N. Taylor's Paper on Air Compressing Machinery at Ryhope Colliery.

SECTION OF THE CYLINDER OF THE UNDERGROUND WINDING ENGINE SHEWING THE PECULIAR CONSTRUCTION OF THE EXHAUST PUMP.



Scale $1\frac{1}{2}$ inch = 1 foot.

A. *Exhaust open at both sides of Cylinder.*

Andw Reid, Newcastle

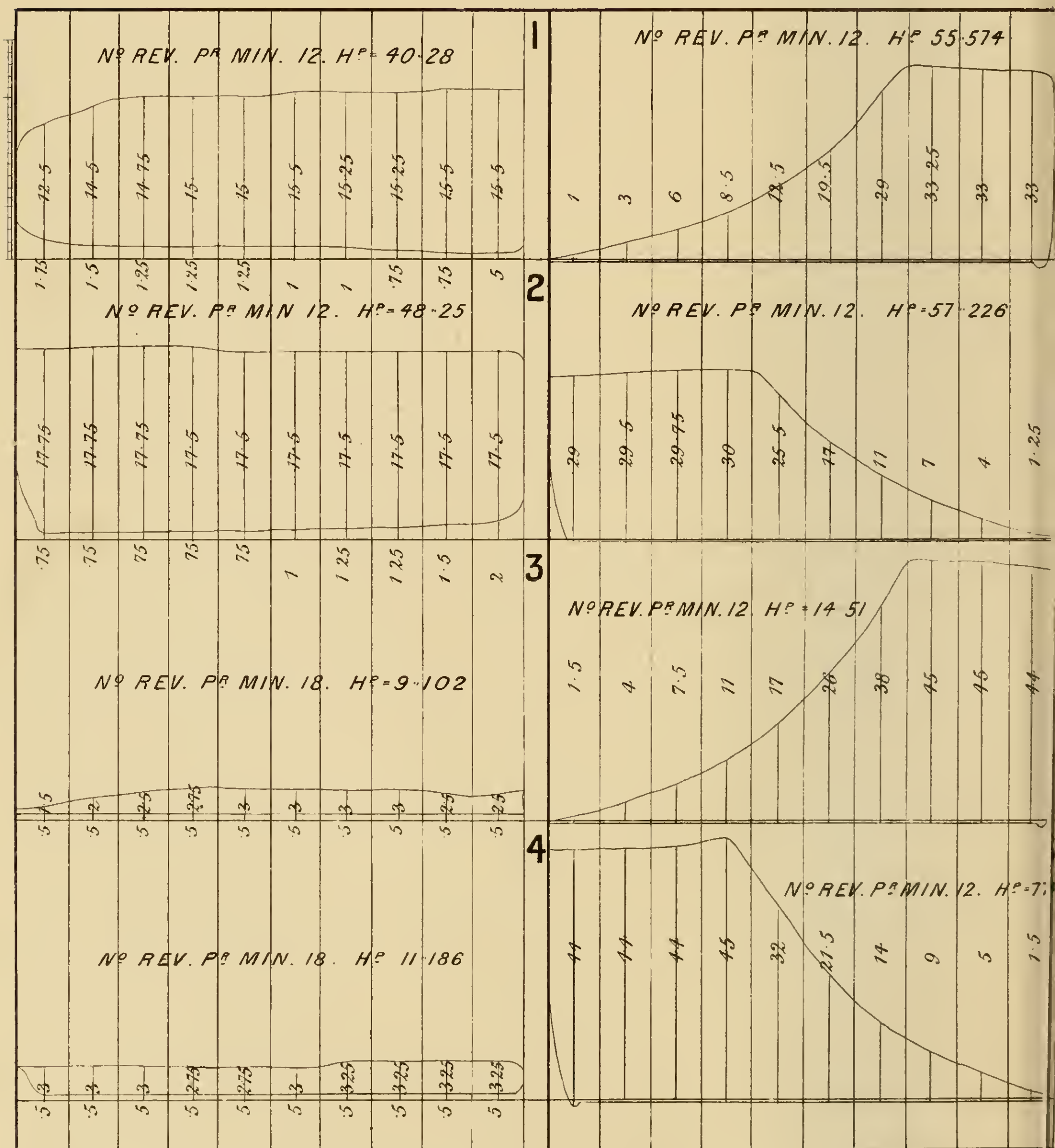
To illustrate Mr. W. N. Taylor's Paper on Air

STEAM ENGINE

Cyl. 32" Dia. Stroke 5' 0"

AIR COMPRESSOR

Cyl. 33" Dia. Stroke 5' 0"

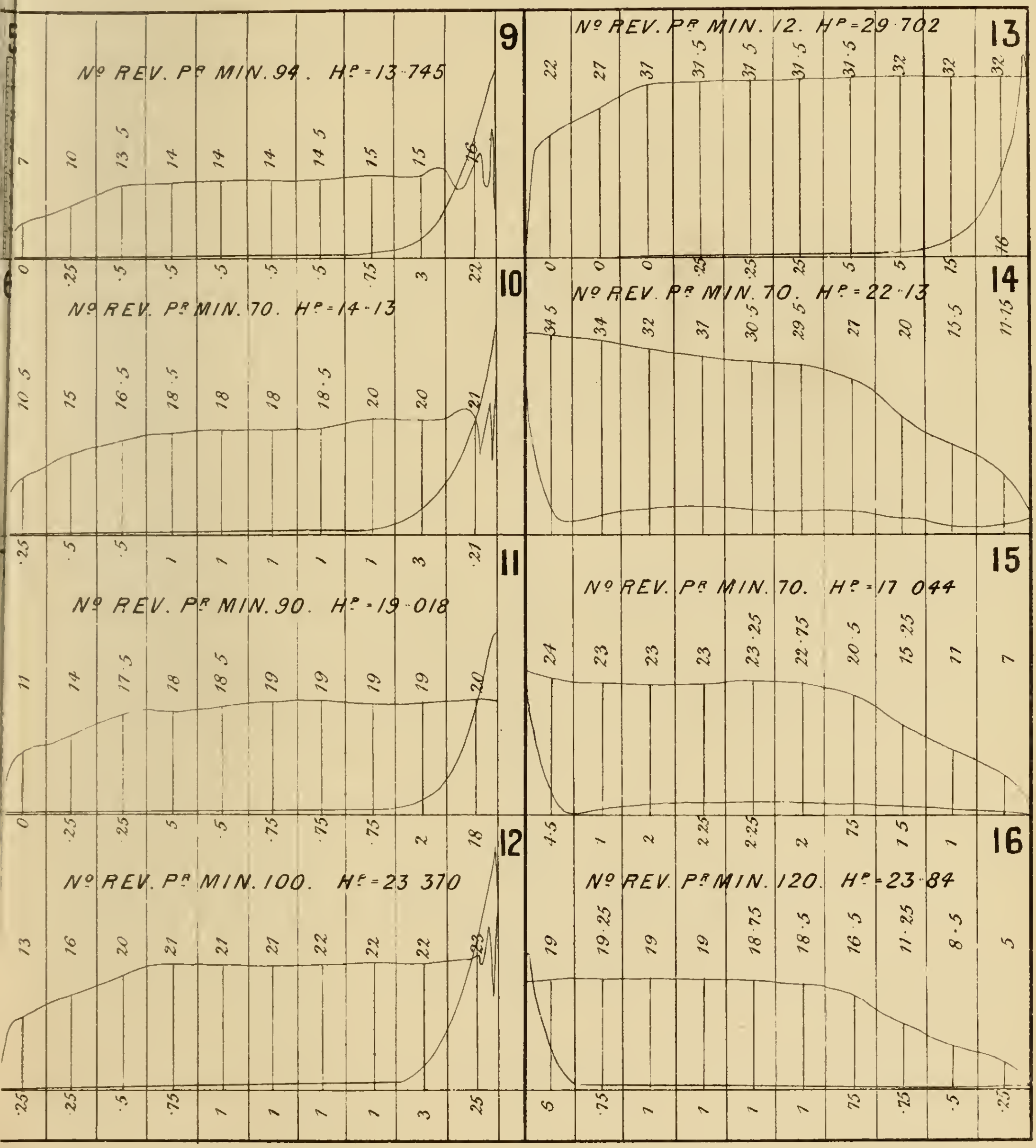


NOTE – Two 32" steam cylinders

...mpressing Machinery at Ryhope Colliery.

INTERIOR ENGINE

Cyl. 14 Dia. Stroke 1' 6"



...re working one 33 air compressor.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, MARCH 2, 1872, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

MR. STEAVENSON IN THE CHAIR.

The CHAIRMAN said, the first business of the meeting was to appoint a member of the Council, in the place of Mr. Hoskyns, whose death they would all lament. The deceased had been for many years the managing engineer at Messrs. Hawks, Crawshay, and Co.'s, and his long and successful professional career and urbane manners had gained him universal respect.

Messrs. Bailes, Morison, Crone, and Waller were appointed scrutineers.

On the return of the scrutineers, Mr. Morison reported that Mr. Richard Hodgson had been unanimously elected.

The report of the preceding Council Meetings and the report of the last General Meeting were read, confirmed, and signed.

The following gentlemen were elected—

MEMBERS.

Mr. JOHN B. EMINSON, Londonderry Offices, Seaham Harbour.
Mr. THOMAS CLARKE, South Benwell Colliery, Newcastle.
Mr. ANDREW FARMER, Westbrook, Darlington.
Mr. ARNOLD THOMAS, M.E., Bilson House, near Newnham, Gloucestershire.
Mr. GEORGE H. HASWELL, Mechanical Engineer, 11, So. Preston Terrace, North Shields.
Mr. WILLIAM HEPPELL, Brancepeth Colliery, Willington, Co. Durham.

STUDENTS.

Mr. OSWALD DYSON, 1, Rye Hill Street, Newcastle.
Mr. WILLIAM MOSES, Lumley Colliery, Fence Houses.
Mr. ERNEST HAGUE, Towneley Colliery, Blaydon-on-Tyne.

The following were nominated for election at the April meeting—

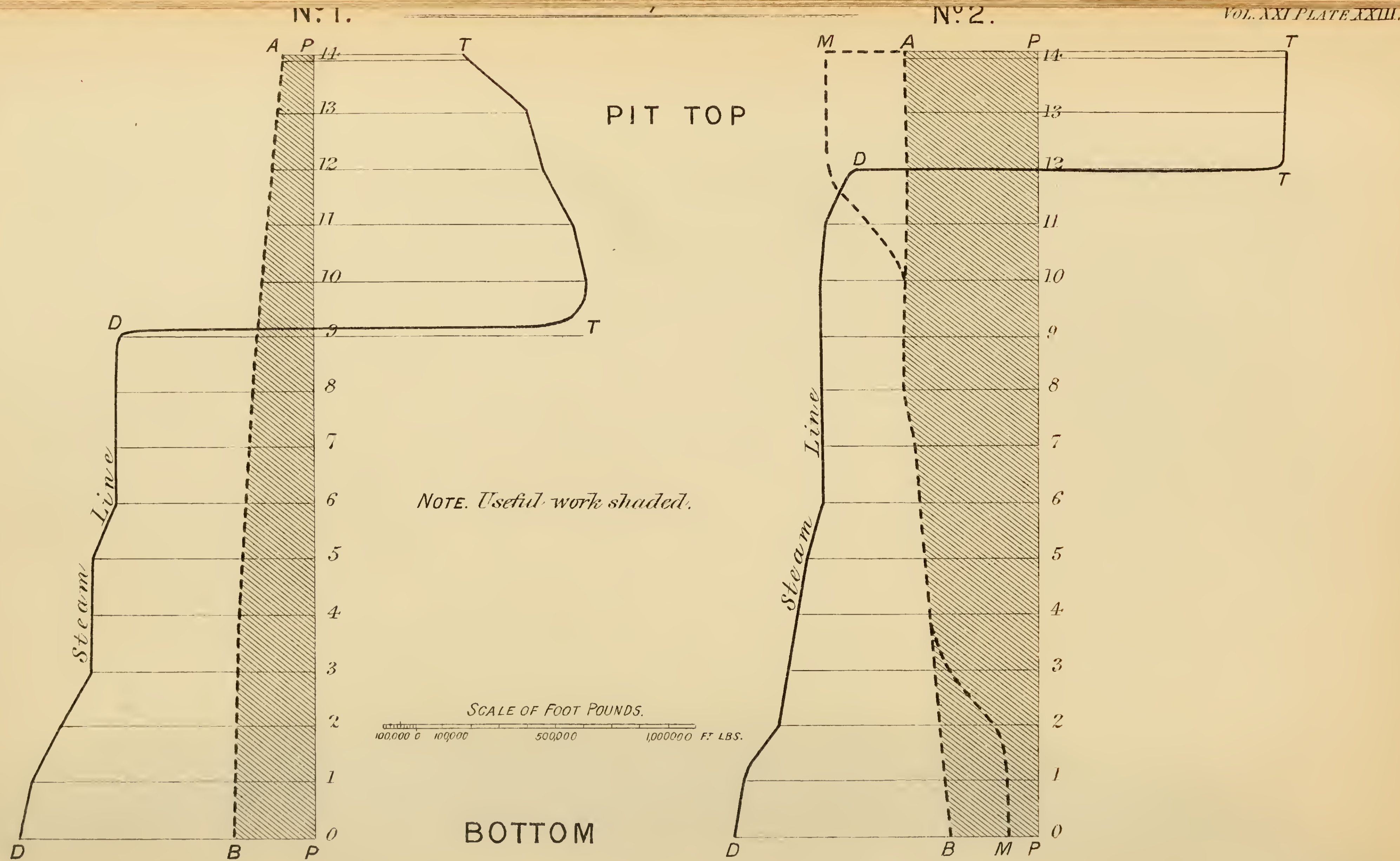
MEMBERS.

Mr. THOMAS WHITELAW, Shields and Dalside Collieries, Motherwell.
Mr. THOMAS JOSEPH, Tydraw, near Pontypridd, South Wales.
Mr. FRED. W. SHALLIS, Bulman Village, Newcastle-on-Tyne.
Mr. THOMAS JOHNSTON, Widdrington Colliery, Acklington.
Mr. EDWARD JOICEY, Coal Owner, Newcastle-on-Tyne.
Mr. JOHN PATTON, Westoe, South Shields.

STUDENTS.

Mr. J. J. HEDLEY, Medomsley, Burnopfield.
Mr. DANIEL JOSEPH, Tydraw, near Pontypridd, South Wales.

The PRESIDENT said, the next business of the meeting was to read a paper by Mr. George Fowler, "On the Scroll Drum."



And.w Reid Newcastle

ON THE SCROLL DRUM.

By GEORGE FOWLER.

In a late discussion on Mr. Daglish's paper upon the Counterbalancing of Winding Engines, reference was made to a series of experiments conducted by the writer upon the actual expenditure of power in large winding engines. These experiments formed the subject of a paper published in the Transactions of the Institution of Mechanical Engineers.

It was shown by these experiments that the uniformity of load to be obtained by a system of counterbalancing, or by the scroll drum, was merely one element in the question of winding economy, and that the mass of machinery in motion introduced dynamical considerations of even greater importance; that, in fact, it was as necessary to compensate for dynamical forces as for statical ones.

Since the date of those experiments, considerable alterations have been made in the working loads upon the scroll drum there referred to, and it may probably be interesting to compare the results of the old experiments with a set obtained under the altered circumstances.

The Kiveton Park engines are a pair of 36 inch high pressure engines, having a 6 feet stroke, and driving a drum varying from 20 to 30 feet in diameter.

At the time of the former experiments, a single decked cage, holding two tubs, carrying 22 cwts. of coal, was used.

Now, a double decked cage, holding four tubs, containing 44 cwts., is in use.

Diagrams 1 and 2, Plate XXIII., show the results of the two sets of experiments.

The lines AB, measured off by ordinates from the vertical PP, show the net load upon the engine for one journey; the included area ABPP representing the total useful work done. The line DDTT gives the actual positive or negative power expended in the cylinders over the same interval; this line being calculated from several series of diagrams taken with the Richard's indicator, The mass of matter in motion may be taken as follows:—

	No. 1 Exp.		No. 2 Exp.
Drum	45 tons.	...	45 tons.
Ropes	$4\frac{1}{2}$,,	...	$4\frac{1}{2}$,,
Cages, tubs, and coal ...	4 ,,	...	8 ,,
Pulleys	$6\frac{1}{2}$,,	...	$6\frac{1}{2}$,,
	60		64

This is exclusive of main shaft, cranks, boss of drum, etc., and the whole mass may, without material error, be considered to travel at the same speed as the load.

It will be observed that in No. 1 series, the engine is run with full steam for nine revolutions, and that it is then reversed and is converted into an air pump for the remaining five revolutions. It is thus usefully occupied 65 per cent. of each journey. In the No. 2 series the engine is run with full steam for twelve revolutions, and is reversed for the remaining two and one-eighth revolutions. It is thus usefully occupied 85 per cent. of each journey.

It will thus be observed that a better ratio of useful effect is obtained with the greater loading.

The time occupied in running is forty-five seconds in both cases.

With regard to the load line, it will be observed that the increase in the loading has entirely changed its character. In the No. 1 series the load for each revolution of the engine commences at 286,026 foot lbs., and diminishes to 114,936 foot lbs.; whilst in the No. 2 series it commences at 330,255, and increases to 467,165 foot lbs. Thus, therefore, in one case the engine is under, and in the other case overbalanced with, as may be seen, a most material improvement in the working of the engine. In the latter case nothing can speak more strongly to this effect than the diagrams themselves. Twelve revolutions of the engine under steam serve to raise twice the load which nine revolutions formerly effected; that is, twice the work is done with one-third more use of the steam cylinders.

It will be observed also that the area of the counter-pressure diagram is reduced by one-half. Thus, therefore, there is evidence of a very decided improvement in the working of the engine. It appears on the diagrams, it is shown by the statement just given, and it is shown by the simple fact that the engine has just doubled its useful effect.

Whilst, therefore, the Kiveton Park scroll drum must now be considered a very successful application of the principle, it still shows clearly that farther and most material improvements may be made by a

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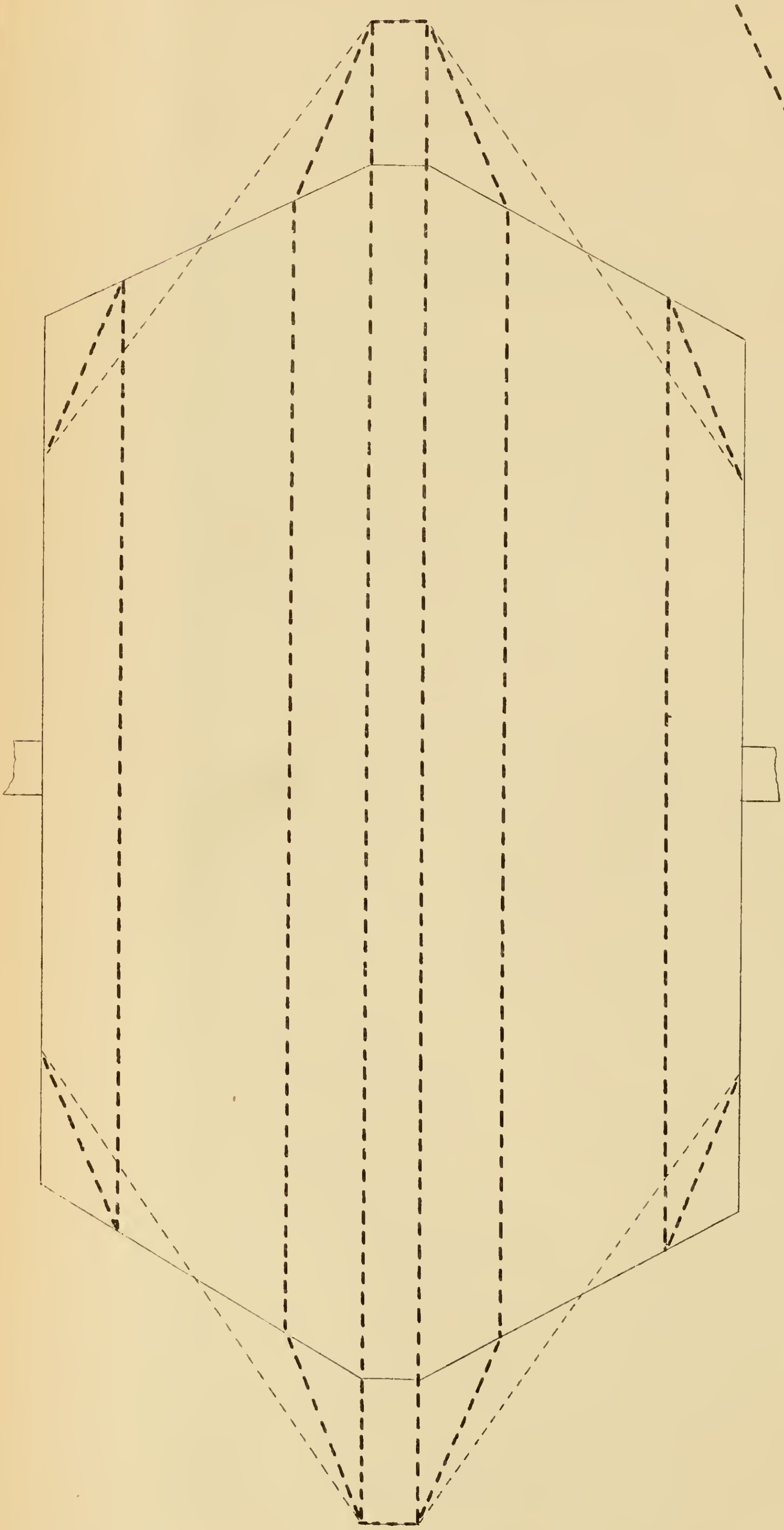

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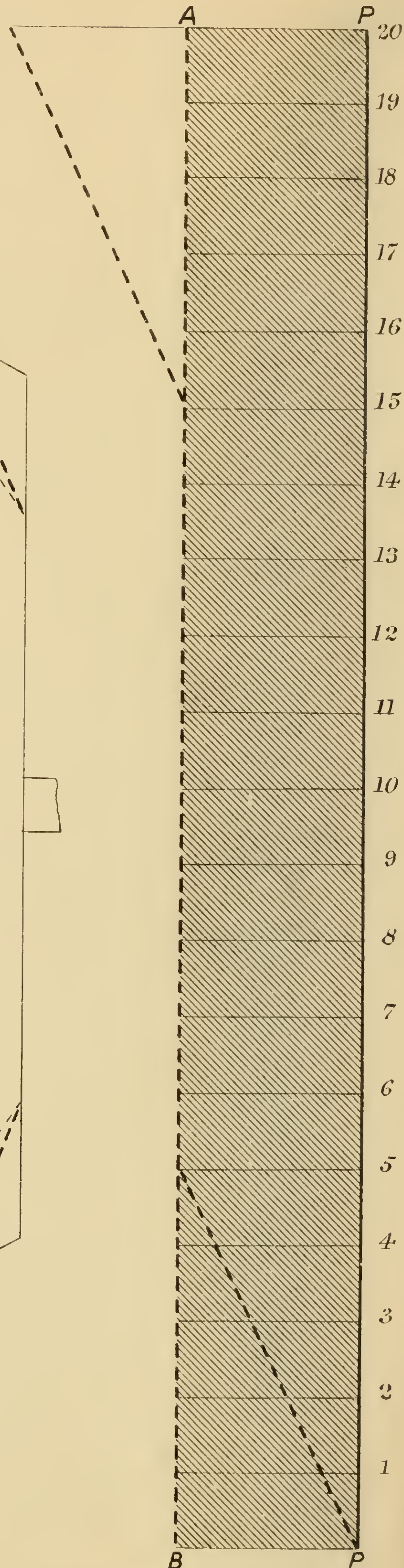
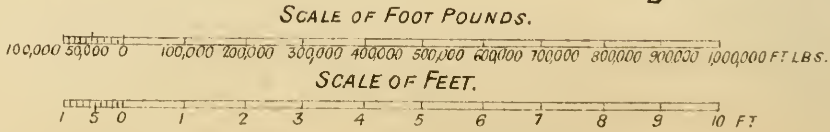




Andw Reid Newcastle

reduction of the weights of machinery in motion, and by a modification of load line, to neutralize the effect of that amount of weight, which is unavoidably necessary.

At the Kiveton Park Colliery the mean velocity of the cages is 31·5 feet per second; the maximum velocity probably 45 feet per second.

To get the 64 tons of matter up to this speed an amount of power is absorbed equal to 4,530,176 foot lbs., and this is represented graphically by the line DD.

In other words, were the cages unloaded, five revolutions of the engine under full steam would be required to get up the speed of the machinery. This power is finally re-absorbed by the counter-pressure work, or by the break, and the capacity of the engine to produce useful work is thus diminished by both these amounts.

This is clearly shown by both 1 and 2 diagrams, in which the steam power exerted is three times greater than the useful work done in the early part of the run.

The first step, therefore, is to cut down the weights. Massive cast-iron spokes and drum rings must give way to wrought-iron spokes and wrought-iron grooves.

There is no reason why a well-designed drum should not be built on this principle of thirty feet in diameter, at from 15 to 20 tons. The other modification required is in the form of the load line. This ought to take the direction shown by the line MM, the object being to so lighten the load at the commencement of the run that the power of the engine is expended for the most part in getting up the momentum of the machinery; whilst, at the termination of the run, this momentum comes into action in assisting the engine in completing the journey.

For two or three reasons, which it is not necessary here to detail, it is maintained that, for the depth of 400 yards, fourteen full revolutions of the engine are too few for the development of the best results; increasing the number of revolutions to twenty, and estimating for the following working loads—

Cage and tubs	50 cwts.
Coal	50 „
Rope	30 „

it will be found that a drum varying in the proportion of 7·5 will give the straight load line shown in Diagram 3, Plate XXIV. This would be a drum varying from 15·91 to 22·28 feet in diameter.

To estimate the momentum of the machinery the following weights are assigned to the moving parts :—

Drum	15 tons.
Ropes and cages	8 ,,
Pulleys	7 ,,
Coal and tubs	5 ,,
	35 ,,

The time occupied in the shaft journey at Kiveton is 45 seconds. With a lighter drum and modified pitch there is no reason why the time should not be reduced to 40 seconds.

Assuming that five revolutions of the engine are accelerating and five diminishing in speed, the maximum speed of running would be $\frac{1200}{30} = 40$ feet per second.

To ascertain the power absorbed in getting 35 tons up to this velocity the following formula is available :—

$$P = \frac{v^2}{2g} M :$$

where P = work done in foot lbs.

,, M = weight of machinery in lbs.

,, $\frac{v^2}{2g}$ = h height a body would fall freely in space to acquire given velocity. Substituting figures we have

$$P = \frac{1600}{64} \times 78{,}400 = 25 \times 78{,}400 = 1{,}960{,}000.$$

The question, therefore, for consideration is how to expend this 1,960,000 foot lbs. of potential energy usefully upon the shaft load.

The simplest method of attaining this end is so to modify the rise of the drum, that the ascending cage shall increase, and the descending cage diminish, its velocity to an amount sufficient to absorb this power, or a considerable portion of it. To preserve a proper proportion, this increase and decrease of rise should be uniform at both extremes of the drum, and it may thus be ascertained.

The weights affected by an alteration of diameter are the cages, coal, and tubs, and so much of each rope as is in the shaft. This amounts to 180 cwts., or 20,160 lbs. It is immaterial for purposes of calculation whether a greater amount of travel is given to the ascending load, a less amount to the descending load, or whether it is distributed between them, the action on the matter in motion being the same in any case. If, therefore, we divide the potential energy of 1,960,000 foot lbs. located in the matter in motion by 20,160 lbs., the ascending and descending weights, we obtain a resultant $\frac{1,960,000}{20,160} = 97$ = number of feet the ravel of ascending cage must be increased and of descending cage liminished, to use up or absorb this energy. If this be effected in the five initial and terminal revolutions, we have $\frac{97}{5} = 19{\cdot}40$ feet per revolution $= \frac{19\ 40}{3{\cdot}1416} = 6$ feet increase, or decrease in diameter of drum. There are, however, one or two practical considerations to be had in view in the introduction of this modification. Thus, the difference in diameter must at no point be so great, that the engine cannot be moved from a state of rest.

In the Kiveton engines, the steam power is at any point treble the statical load. Taking it in the assumed case at twice the statical load, we have the following:—

With drum of uniform statical load, the net load on engine in every position of cages is,

			Pounds.
Loaded cage at bottom,	Cage, tubs, coal, rope,	$130 \times \frac{15{\cdot}91}{2} \times 112 =$	115,824·8
Empty cage at top,	Cage and tubs,	$50 \times \frac{22{\cdot}28}{2} \times 112 =$	62,384·
			53,440·8

It is required to ascertain the terminal diameters which will double this load or increase it to $53,440{\cdot}8 \times 2 = 106,881{\cdot}6$. The increase and decrease of diameter being the same, it is necessary only to find the value of this:—

Let x = the value required.
a = larger diameter of scroll of equal loading.
b = smaller diameter of scroll of equal loading.

Then, when the loaded cages are at pit top, which will be the most unfavourable statical loading on engine,

$$5600\,(a + x) - 4480\,(b - x) = 106,881{\cdot}6,$$

$$\text{and } x = \frac{53,394}{10,080} = 5{\cdot}29 \text{ feet.}$$

Thus, the drum would vary from $22{\cdot}28 + 5{\cdot}29 = 27{\cdot}57$ feet to $15{\cdot}91 - 5{\cdot}29 = 10{\cdot}62$ feet in diameter.

This range in diameter is rather less than would be adequate to expend usefully all the power absorbed in the mass of the machinery, but it would do so to a very great extent.

It is probable that in practice, instead of giving a variable slope to the drum, one uniform rise would be better.

It would unquestionably admit of simpler construction.

There is no reason why, with a drum of this design, a pair of 30 inch cylinders, working at the same boiler pressure and with the same depth of shaft, should not raise a greater weight of coal, than the 36 inch cylinders are now raising at Kiveton, and that with less wear and tear and very much less steam consumption. This, of course, means a cheaper engine in first-cost, and a cheaper engine in working cost, and that to a degree by no means inappreciable.

The Chairman remarked, that it was not usual to say much on the day on which a paper was read; but he believed it would be quite clear to them, that it was a very excellent paper, and that it treated on a subject of very great importance. Of course, the question of first cost formed an item of great consideration, and these immense and complex drums cost a large sum of money; so it became a question whether the result could not be obtained more advantageously by putting this money into the engine. The object of the scroll drum, as they all knew, was to regulate the power created, so that it should agree as nearly as possible with the work done; and those who observed a brakesman at his duties would see that he did to a great extent, by hand labour, that which the scroll drum is introduced to effect. He did not mean to say that the engineman could do it so effectually; but still, he thought, he might in a great measure meet the necessities of the circumstances, and these should be taken into consideration as well as the mere dynamical and statical effects. If any gentleman wished to make any further observations, he was sure the meeting would be glad to hear them. He asked them to give a cordial vote of thanks to the reader of this paper.

A vote of thanks was carried unanimously.

DISCUSSION ON MR. BAINBRIDGE'S PAPER ON THE DIFFERENCE BETWEEN THE STATICAL AND DYNAMICAL PRESSURE OF COLUMNS OF WATER IN LIFTING SETS; AND MR. HALL'S PAPER ON THE SETTLINGSTONES PUMPING ENGINE.

Mr. Boyd then took the chair, and said, the next business was the discussion on Mr. Bainbridge's paper, "On the Difference between the Statical and Dynamical Pressure of Columns of Water in Lifting Sets;" and as Mr. Hall's paper, which was the next paper to it, seemed to embrace very many points of the same character, he thought they might be discussed together. He would call their attention to the very great augmentation of pressure which takes place in certain portions of the stroke of pumping engines, and he would be glad if any gentleman there would give them a satisfactory reason for it; for every one who had had much to do with pumping engines knew that it was a very great source of expense. He happened to have a high-pressure engine at a very considerable pressure of steam, used for nearly 20 years, and his difficulties were not in the bursting of the bucket doors, nor in the bursting of the pumps, which seemed to have been old enough to have got accustomed to the pressure of a sudden shock of a high-pressure engine in its revolutions; he had not these difficulties, but he had others derived from the same cause, viz., the breaking of the spears connected with the bucket, and was often at very great labour and very great expense to get these repaired; he had no doubt now, since he had seen Mr. Bainbridge's very elegant form of indications, that he might have avoided many of the frequent accidents which took place on those occasions. With regard to the use of the fly-wheel, he thought it could only be applied with advantage to short depths, such as 35 or 40 fathoms; but when it came to very large sets and greater depths, as in the case of an engine he might mention to them at Lambton Colliery, the same results were not obtained.

Mr. R. B. Sanderson had not the paper before him; but he thought he could lead them to some information in connection with another branch of engineering, which would throw some light upon the subject of this paper. They were aware that, as the Chairman of the Newcastle and Gateshead Water Company, he had some experience in pumping, and with the inconvenience caused by fractures; and they did not estimate fractures merely by the mischief that was done, but by the results which they caused upon the supply of water to a very large community. He might mention at once that pretty nearly the same state of things, as that described in the papers, arose in connection with the very large double engine they had at Newburn. The length of stroke was, he thought, 10 feet; the plungers, two in number, one on each side of the engine, were 34 inches in diameter; the lift was equal to about 270 feet, and the length of the main, through which the engine had to pump, was about four miles. Upon these four miles there were, as they knew, a number of lead joints, and the effect of the blows upon the water was not only to break the pipes, but to cause leakage from those joints. When that engine was first started, it was not in a very perfect state. It was started with air vessels, 5 feet diameter and 18 feet high, 15 feet being filled with air; but the means of charging these with air not being perfect, the consequence was, that the engine had to act without them. This was in 1867, and he was speaking from memory; but he thought that pretty nearly the same effect was observed which had been described by Mr. Bainbridge; for by means of pressure gauges, which they had upon the mains for the purpose, they found that the oscillations were very numerous, and represented as much as 100 feet of water pressure, above and below the pressure due to the column in the mains, pretty much in the same way as was indicated in that paper; and, until the air vessel was put right, they broke the 24-inch mains in two or three different instances; but as soon as the air vessel was perfected, the diminution of oscillation was from 100 feet on each side of the main pressure, making a total of 200 feet, to a total of about 30 feet, when one side of the engine was working, and 20 feet when both sides were going; the diminution of oscillation in the latter case being caused by the engines being coupled so that their strokes crossed each other. The air vessel was, therefore, the remedy for that oscillation, and he would be very glad to give the Institute a short paper on the matter; because he thought it might be the means, perhaps, of devising a remedy suited to the bottom of a pit. He was quite aware that it would be exceedingly difficult to put an air vessel of the size he was speaking of in a pit, but it did appear to him that by altering its general proportions, so as to obtain the same amount of cubic contents, they would be able to find it a practical remedy for the inconvenience described. He might mention that the effect of the air vessel is simply this: when the plunger ram comes down, of course it sets the whole column of water into motion, and accordingly, when the ram stops, the water continues still to pass forward for a short interval of time till it comes back again upon the upper valve, which shuts with considerable force. One-half of the force communicated by the down stroke of the plunger drives the water into the pipes, and the other half forces it into the air vessel, and when the stroke is over, the water in the air vessel is ejected by the compressed air, and keeps up the motion of the water in the mains, when the ram is rising to make its second stroke, and in that way the current of water is nearly, not entirely, continuous, but is so far continuous that the only difference observable in the pressure, when the air vessel was used, was 20 feet. They had gauges near their air vessel which show exactly the height of the water in them, and they could see by that means, that just about a quantity of water equal to half the contents of the ram passes into the air vessel, and is given off again by the pressure of the air, when the engine was rising again to give its stroke; thus it produced a continuous stream. Now, he thought it would be possible in many shafts to put up a long main, so as to form an air vessel sufficient to take off a very great part, not, perhaps, the whole shock from the pumps, and thus prevent fracture. He was aware of the practical difficulty; but if the principle was before gentlemen conversant with the matter, it was possible they could devise something which would act as an air vessel in preventing fracture of the machinery, and the loss and damage in consequence. If it had not been for the air vessel, and another improvement which he would speak of, the Cornish engine which was so large a success in London and in all water works, would have been practically useless. They could not have stood the constant fracture of the mains and stoppage of the supply from such blows as the engine he was speaking of gave, until the air vessel was attached to it. There was another matter in connection with these large engines which he thought in colliery work had not been sufficiently attended to: that was the form of the clacks, particularly of the suction clacks. Some of the suction clacks in their engines were double beat valves, and on the engines at Newburn they had what were called quadruple valves. They rise a little way, and the rise is so small as to prevent that tremendous blow which the common valve gives when it shuts down, and which had been so often a cause of fracture in pumps. He would be very glad—as he thought it was an interesting subject—if they would allow him to give a short paper on it, and to describe some of those appliances he had been speaking of. He would also state, that unless they took means to keep the air vessels charged, they lost about half an inch of air from the air vessel upon every stroke. In connection with their engines at Newburn, and all the engines where they had air vessels, they had a peculiar form of air charging arrangement. He was rather fond of reading on these subjects, and he got hold of a very beautiful French work—a shilling work only in price—but an admirably got up one, belonging to the Library of Wonders (Bibliotheque des Merveilles); it gave a diagram of a mode of air charging adapted in the air vessels on the Seine for the supply of some part of the water of Paris, and this mode they adapted to their air vessels, and it worked so as exactly to balance the loss of air by each stroke. If it was not so replenished, the air vessel would become entirely empty, and practically it would be no air vessel at all. There were other ways of charging air vessels besides that, which he would describe in the paper; but it was as ingenious as it was simple, and besides that it had some other advantages over the common mode. They might charge them with a sniff-cock at a certain part of the pump; but that admitted air not only into the air vessel but also into the body of the water, which did not practically matter in some works, but in water works it was very mischievous. It accumulated in the bends of the pipes, and there stopped the supply of water, and, in addition to that, was a frequent cause of fracture. They, therefore, did not like air introduced into the body of the water if they could help it. The small apparatus he alluded to admitted the air into the air vessel without passing it into the body of the water.

The President was sure the Institute would be very much obliged to Mr. Sanderson if he would add a description of this little apparatus to his paper.

Mr. Southern would suggest that Mr. Sanderson should take into consideration the size of the pump he had to deal with, and whether he would not do harm by introducing a system of the kind he mentioned in pumps of the ordinary pit size.

Mr. Sanderson—They had rams and valves of different sizes on their different engines, and they had invariably air vessels upon them, and he did not think they would find the size made any difference, provided the air vessel was adapted to it.

Mr. Bainbridge thanked the President for his remarks on his paper, but was afraid he might have given a somewhat wrong impression to members who had not read it. He had not confined his paper to the simple experiments, but had endeavoured to show the cause of the shocks, and how such shocks could be prevented. The cause was simply that their engine was badly balanced. Their stroke was made much faster, and with much greater velocity than with the Cornish engine under favourable circumstances. In an engine well balanced, and where the speed could be reduced to a minimum at the beginning and end of the stroke, the shock would be very little felt. With double acting force pumps working at high speed, experiments had been made which showed but small difference between the statical and dynamical pressure of the column. In their own case, unless they went to a very great expense in altering the arrangement of the pumps, they could hardly change their present condition; and he had, therefore, been satisfied to make his pumps twice as strong as before. He ventured to say, that the character of the paper he had brought before them, was such as to show the great importance, where an engine was badly balanced, of having the parts exposed to pressure, very strong. An air vessel, he believed, would act admirably in situations where the area of the orifice from it to the main pump was as large as the area of the pumps themselves; this, however, could hardly be effected in the case in question.

Mr. Clark stated, that the President was right in stating that the application of the rotary motion by the addition of a fly-wheel to the large pumping engine at Lambton, was not so efficacious as it had been in Mr. Crawford's first application of it at Elvet, Lumley, and other places.

Mr. Waller objected to the statement put forth in the proceedings as to water following a plunger, which had a velocity of only about 70 feet per minute, and meeting it with little, if any, elastic medium, at the rate of between 5 or 6 feet per second, as being contrary to fact. All pumps come to rest gradually; there is no sudden stoppage, as the action of the engine is first to check, and then to arrest, the motion.

If the title Statical and Dynamic Pressure really represented the subject under consideration, it might be argued that while a stationary column of water can be readily calculated as to its statical or dead weight, its dynamic force is entirely dependent upon its speed; thus the pressure on the rope of a winding engine varies with the speed —the insistent weight of a railway train upon the rail is much altered by the velocity—and so the pressure upon the inside of a pipe must be affected by the motion and speed of the water within it.

The paper which the writer contributed to the proceedings of this Institute upon Pumping Engines was chiefly directed to their relative cost, and the consideration of the best kind of engine for the purpose, and may be supplemented, if this discussion is adjourned, by some illustrations taken from the engines there considered. The weight of the column of water being known and the velocity determined, it is easy to ascertain the power required to put it in motion—a power which will be in excess of the statical force by a quantity sufficient to overcome the friction and give the velocity, and this force may be called the dynamic pressure.

The force which broke the bucket door piece has been shown to be greatest when the engine and pump are at rest at the end of the stroke, and is in reality to be estimated by the lift of the clack, the leakage of the clack and bucket, the play of the rods, and other internal causes, too often thought too trivial for consideration, but which together resolve themselves into a power of considerable amount, and suggest the question, What force would be given out by the blow of a weight of so many tons falling 9 to 12 inches? This is the real question raised by the fracture of the bucket door-piece, and it may be easily proved to be so by the sudden closing of an ordinary domestic service-pipe tap, which, when opened, will, for the instant, scarcely run, but then coming with great velocity, gives a violent thud when suddenly stopped by the closing of the tap. This unknown power, which is to be heard, if not seen, and the force of which may be estimated by sound, acting more directly and locally upon the flat surface of the doors and door-pieces, is the same in the service-pipe as in the pumps, and in all questions like that under discussion should be distinguished as the percussive force from static and dynamic pressure, and the centre of this force will be found near the bucket door.

The condition of water being lifted by a bucket is different from that which is being forced by a plunger. In the Cornish engine there is always an air cushion under the ram; careful watching shows this to be about 6 to 8 inches of the stroke, and experiment has proved that with a 9-feet stroke the average length was only about 8 feet 4 inches. This is the only point upon which the crank system of pumping can claim any advantage over the other—inasmuch as it gives a more regular length of stroke.

There is one other point opened up in the discussion, the constant flow of water through pumps attributed to the *vis viva* of the rising column of water. All the experiments that have been made with pumps have proved that the actual delivery of a pump is less than the theoretical capacity. There are globules of air which are intimately mixed in the water and form a compressible body, but which escape upon delivery. To account for the constant discharge of water from a pump it is only necessary to imagine the clack to be tight, the bucket descending, and so many feet of 9 inch square pump rod introduced into the water displacing its own bulk and forming the *vis viva* which has deceived Mr. Steavenson. The following description of a pump, in which both a bucket and a plunger work in the same barrel with but one set of valves, will serve to explain his (Mr. Waller's) meaning. Through the stuffing-box, in the cover of a $12\frac{3}{4}$ inches working barrel, passes a plunger of about 9 inches diameter, and this plunger terminates in a bucket of the full diameter of the pump, in such a way that the plunger offers no obstruction to the action of the bucket valves. On the upward stroke the pump will draw about 16·2 gallons per yard through the suction valve, and will send about 8·1 gallons per yard, or half of this quantity, through the delivery valve. In the down-stroke the ram passing into the full barrel, the water in which is prevented escaping by the suction valve, displaces the other 8·1 gallons per yard, and forces them through the delivery valve, thus keeping up a constant stream of water. One of such pumps was erected at Ashby-de-la-Zouch, and another at Selby, besides some in other places. The lift of the clack is a consideration of the first importance, as also the speed of the pump. It has been found that the best delivery has been obtained at about 84 feet per minute, regular speed. The tremulous lines in the diagrams illustrating the various pressures of the bucket lift prove too great a speed; those in the plunger lift may be due only to the air present in the water, as in corresponding cases an indicator diagram would show water in the steam. Mr. Sanderson has referred to blows on the mains and consequent fractures of the pipes, until a proper means of keeping the air vessels charged was adopted. It may be interesting to remark, that in the engines of the Liverpool Water-works, referred to in the writer's paper in August, 1867, all the engines had either air vessels or stand pipes, and upon examining the pressures in the mains by means of a pressure-gauge, there was in all cases a vibration or pulsation, and he believed that the same would be found in all pumps, more or less, according to the size of the pipe and speed of the engine. This is shown in a report made to the Corporation of Liverpool in April, 1849, and will be interesting as an addition to the paper promised by Mr. Sanderson, and which he (Mr. Waller), upon the request of Mr. Steavenson, promised to include in his paper.

Mr. Bainbridge suggested that this report would form a valuable addition to the discussion.

The President said, they were very much obliged to Mr. Waller; the report would come in very well with Mr. Sanderson's remarks upon the air-vessel. As they had the presence of Prof. Herschel, perhaps the professor might feel inclined to make some remarks.

Prof. Herschel said, with regard to what Mr. Bainbridge remarked in his paper, and also what the next speaker said, his attention was drawn to the explanation given in the paper as to the probable cause of the great rise of pressure upon the termination of the stroke, which was suggested to arise from the momentum existing in the column throwing the water up from the bucket, and allowing it again to fall with a blow. Now, if attention had to be directed towards this as a dynamical problem, it certainly did appear that the water would rise; without reckoning friction in passing, it would rise some 3 or 4 inches in the case of such a column as that described in the paper, and with a velocity of about 5 feet per second. He found the resistances of friction were almost insignificant in the case. But this question arose, does the bucket come to a stop in the sudden manner supposed—was this taken for granted, or did it really do so? Because, without it did so, they would not have the rise of 3 or 4 inches from the bucket, but a considerably reduced rise; and it was in fact the suddenness of the stoppage of the bucket, which was a very large element in the question, and which would determine whether the water rose or not. If it did not take place at all, he did not see how any blow could be occasioned by that rise. If, however, it did take place, they then had the water suddenly brought to rest from a fall, of say about an inch or upwards; it would undoubtedly produce a shock, but he did not see how that shock could be estimated. The elasticity of water, although difficult to investigate, was known, and the elasticity of cast iron was also well known, but without the elasticity of the joints and seams, they would have difficulty in estimating the actual pressure found on a square inch, which would be the effect of that shock. He had had pointed out to him a fact, which he had not been aware of, that in the up-stroke of all pumps with plungers, and lifting pumps with buckets, it was customary to observe, that the water did not follow in close contact with the bucket or plunger; this must be the case when the plunger or bucket rises, as is the case with beam engines with a pretty nearly uniform speed, beginning and ending with nearly the same speed. The water did not begin to flow fast. They knew that under the pressure of the atmosphere, which urges the water to fill the vacuum behind the plunger or bucket, it should enter with a speed due to the fall of about 34 feet; but it would take a little time to attain that speed, especially if obstruction in the valves occurs. Therefore, although it would overtake it at last, it might happen that during the 9 feet stroke the water did not reach up to the plunger or bucket. The bucket went to the top with, say, a speed of 5 feet per second; the water came after it, and by the time the water had got to the top, it had attained nearly the speed due to falling about 25 feet, that is, a speed approaching about 40 feet per second. But the friction has been resisting it and the speed has been reduced, perhaps, to 20 feet or less; still the fact remains that it has not kept up to the bucket, and is making up for lost speed at the end of the stroke; the water would then strike the bucket at the speed of nearly 20 feet per second. Might not the effect of this blow be felt as a shock in the water above the bucket and the valves, and produce a similar shock to that observed at the end of the stroke, and attributed to some unknown cause? He would like to consider this as the reason of the shock, from the fact that he did not observe in the diagrams of Mr. Bainbridge a diminution of pressure, previous to and corresponding with the rapid increase, which takes place when the plunger had made its up-stroke and had come to an end. When the bucket had lifted the water up, they did not find in the upward movement of the water that there was that *almost total* relief from pressure, which would take place if the column rose from the bucket by its own impulse. Referring to the well known combination of the plunger with the lifting bucket described by Mr. Waller, it was introduced into the Richmond and Bristol water-works by Mr. David Thomson, and lately in the Lambeth water-works, and by its action, both in the down and up-stroke, it throws the water out. It had occurred to him that the continuous rise of water, after the up-stroke of a bucket had been completed, which had been alluded to, probably did not depend upon any dynamic force remaining in the water at the end of the stroke; but might, perhaps, be explained by the fact mentioned by the last speaker, that the pump spears followed the bucket down and continued forcing the water out, a principle which was, in the plunger-bucket pump, turned to practical advantage; but it did not secure the effect of a continuous stream, and therefore, did not relieve the shock. The air vessel evidently supplied them with the real remedy for this.

Mr. Bainbridge said, he congratulated the members on having the assistance of so eminent a gentleman as Professor Herschel in the discussion before them. Might he ask the Professor, if he had calculated that it was possible, that the water, having a velocity of 5 feet per second, could rise a distance of 4 inches from the bucket?

Professor Herschel said, at the speed of 5 feet per second, suddenly arrested, the water column would continue to rise three inches and a half before it came to rest; and if no water followed it through the bucket to support it, it would fall back from that height upon the bucket valves, and strike them with the same speed of 5 feet per second with which it began to rise. The whole time taken by the column of water to rise and fall would be about three-tenths of a second; and the effect of friction, in a smooth iron pipe of the size and length described, even at the greatest speed of 5 feet per second which the water can possibly have during its upward and downward motion, would only add as much resistance as about 2 feet head of water on the top of the water column, 340 feet high, would produce; the effect which that resistance would have in diminishing the time and height of the rise and fall of the column may be quite safely overlooked.

Mr Bainbridge thought it impossible, when the bucket went up at the rate of 5 feet per second, for the water to leave the bucket; the water being in motion at that velocity, and suddenly stopped, probably caused the shock. Mr. Herschel stated that he was not quite sure whether the bucket at the top of the stroke really came to a sudden stop. He might say, they were unfortunately placed under such conditions that he could not help seeing exactly what happened. They had two pumps with 100 yards lift upon one level, and one of them was not at work. He had the bucket door taken off, and had a man to watch the exposed bucket while he himself took the indications, so that they saw exactly the action of the bucket, which stopped suddenly, and stood very often at least two seconds at the top of the stroke. He was obliged to take these diagrams, not by an indicator, but by sitting near the gauge and sketching them, and, as slight alterations might occur, he took care to let at least 100 strokes go before finishing the diagram.

Mr. Steavenson said Mr. Waller was mistaken in observing that when a large body of water was in motion there was no *vis viva*. As a fact, they knew that was not so, and he thought the Professor quite appreciated the view he took. He suggested that Mr. Waller should have some means of immediately checking the flow of water as soon as the bucket rises to the top of the stroke, and he would guarantee he would burst any pipe he could put there. He did not speak of a ram plunger, where it was impossible for the water to pass, but he spoke of a bucket with valves; in such a case he had observed frequently that when the bucket arrived at the end of the last stroke, the water continued to flow through the clack, the bucket, and the valves above.

Mr. Waller contended that it had never been proved that a pump could deliver its full quantity under pressure. What was gained at the end of the stroke was lost at the beginning. To assume that a pump would deliver more than its cubic contents, the supposition of which Mr. Steavenson's remarks would seem to warrant, was a fallacy which had been exploded by actual experiment. Even in a Cornish engine they did not get the full quantity due to the length of the stroke; and, in addition, they had a heavy per centage of loss in working from air and other causes.

Mr. STEAVENSON said, Mr. Waller did not admit of machinery being imperfect, and was not making allowance for the water leaking past the clacks, and the pump not delivering what it ought to do. But, he (Mr. S.) said, take a pump in perfect order, mathematically perfect, then the bucket should deliver the exact amount due to the area of the working barrel and the length of the stroke, and not only that, but when this large body of water was in motion it would continue to flow on. If they took into consideration the actual work done by an ordinary pump, Mr. Waller was right. If they referred to the proceedings of the Institute, they would find he had shown that in the practice even of good pumps they did not get what they ought to do; but in pumps mathematically perfect, when a certain amount of water was in motion, more was delivered than was due to the capacity of the working barrel.

Mr. WALLER said, the argument which assumed that the water continued to flow through its elasticity after compression in the barrel must be fallacious, since, if the water expanded in the one case, they must assume that it was compressed in the other. The theoretical contents of the pump could not be obtained in any way, any more than the perfect vacuum, which must be also assumed before a mathematically perfect pump could be obtained.

Mr. STEAVENSON was willing to submit the question to Professor Herschel, who was well qualified to judge of its accuracy.

Professor HERSCHEL—The amount of motion remaining in the water after the pump bucket comes to rest, would depend only on the manner in which the bucket ends its stroke. In illustration of a case in which the water would continue to rise after the bucket was brought to rest, he would lay a penny in his hand, raise it, and with his fingers strike the edge of the table; the momentum would cause the penny to rise after the hand had been brought to rest. Thus, when the hand strikes the table with a speed of 5 feet a second, the penny will rise four or five inches. Now, if instead of being brought to rest suddenly, the hand were gradually stopped in the course of that four or five inches, the penny would not leave the hand. So that it is a question of the manner in which the bucket was brought to rest in the last four or five inches of stroke. He questioned if the case had been examined so closely as to allow them to say in what manner the bucket came to rest in the last four or five inches of its stroke. If it keeps up to its full speed until within the last four or five inches of the end, and then moderates its speed during that to the end, the water could not leave the bucket at all, and would constantly follow the speed of the bucket to the last. When the bucket stopped, the water would stop also; there would then be no motion remaining in the water at the top. It was, therefore, he thought, a question to be decided by some nice means of examining and observing the last few inches of the stroke of the pump; and although it was really but a small rise which the water would have with a speed of five feet after a bucket was brought suddenly to rest, yet, to determine exactly the amount of any smaller rise than this, in the short space of time available, the observations would have to be very carefully made. He was not, of course, sufficiently acquainted with the action of pumps to be able to pursue this matter further. Those around him would, therefore, know whether his remarks were of any value.

Mr. Southern thought Professor Herschel could not have given a better illustration than he had done with the penny; because the pump was prevented following up the rise in the water the momentum of the previous stroke had caused.

Professor Herschel—The remarkable fact is that the water should continue to flow while the bucket remains at rest. It might be some effect of the elasticity of the air in the pipes recovering itself from that violent shock, which had been given to it at the end of the stroke. It was difficult to explain how the water could continue in motion for two or three seconds of rest, when the period of that small rise and fall, after stopping the pump, could not possibly exceed three-tenths of a second, which was the probable limit of the time of motion calculated from the rise of five feet a second. After a dead stop, from a motion of five feet a second, they would have the motion of the column upwards for about a sixth of a second afterwards. It then came to rest and fell for the same fraction of a second; its continued motion during the whole period of rest could not be explained by the impulse of the water continuing to preserve it in motion during that long time. On the other hand, if a pump should draw but a small quantity of air, the gradual expansion of that air in rising towards the outlet of the water in the pipe, by displacing a certain quantity of water, as it rose, might perhaps afford a real explanation of the occurrence of a constant flow of water from the outlet during the whole of the time that the engine was at rest.

Mr. Southern said, it was a very common thing, and could be seen frequently over the country, that engines going at the rate of seven strokes per minute, would produce a constant flow to the top of the deliverer. In reply to the suggestion of a member he added that he did not think that, supposing the spears acted as plungers when going back into the pumps, they would produce anything like the quantity that follows after the stroke is finished.

The Secretary thought they ought all to be very much obliged to Mr. Bainbridge for the very great pains he had taken in the preparation of this paper. These diagrams he considered to be most exquisitely done; and they really explained and carried out his views in the most excellent manner. He was sure that Mr. Hall and himself were more especially able to judge of the great care which Mr. Bainbridge had taken in producing these papers, because they were down the Settlingstones pit trying similar experiments, and he assured them that watching an indicator was, under the circumstances, a very difficult operation. With regard to noticing the rise and fall of the bucket, they had a string with a weight attached to it, so that they could also observe that pretty accurately. He did not think that the water ever leaves the bucket, for this simple reason, as Prof. Herschel said, that if it did there would be a vacuum formed, and that would be shown by the indicator immediately. He had the indicator on the suction, and the very instant the pressure was taken off, it was shown on the gauge; and, again, they would see that in the case of the plunger, after it had delivered its stroke and driven the water up the main, and the water had been at rest on the delivery valve, the plunger, as it drew itself out of the pump, still produced a shock, although the water in the rising main had been at rest during a considerable number of seconds. Therefore, he opined there must be a shock due to the incoming water; and he thought that that possibly and probably was more than that produced by the motion of the column above the clack.

The discussion then terminated.

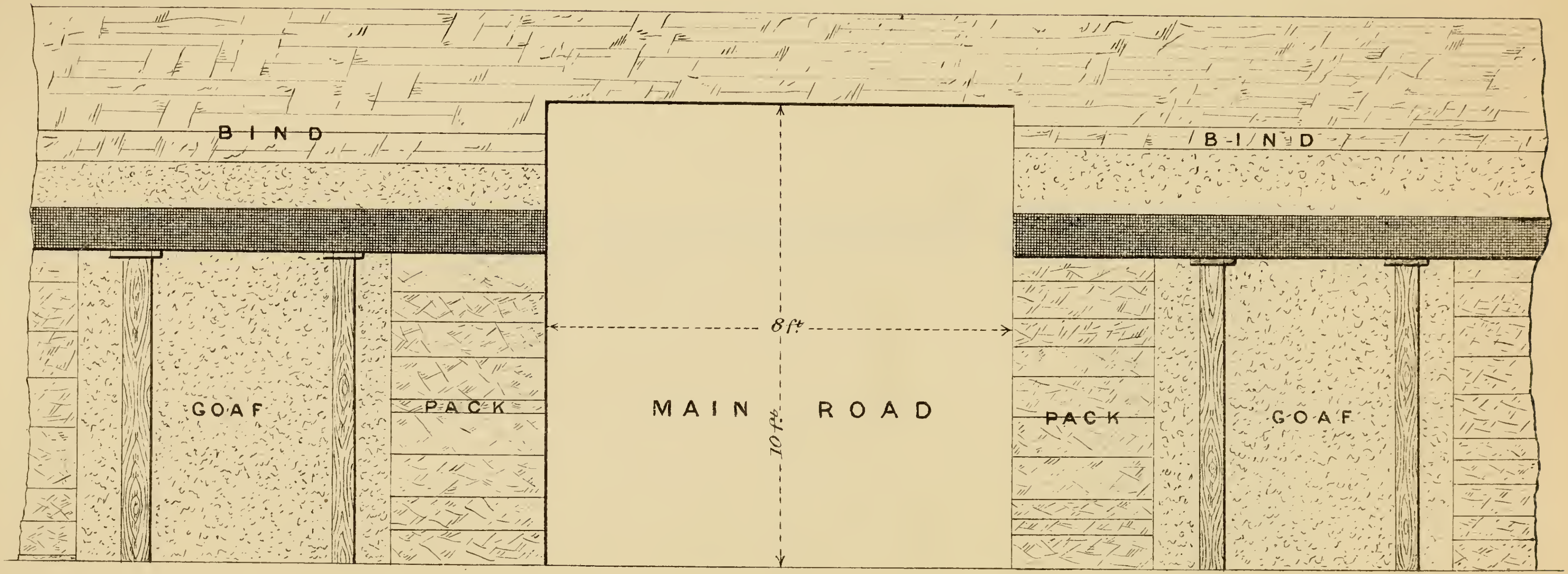
DISCUSSION ON MR. LEWIS' PAPER "ON THE METHOD OF WORKING COAL BY LONG-WALL AT ANNESLEY COLLIERY, NOTTINGHAMSHIRE."

The President then invited observation on the paper upon the working of the long-wall by Mr. Lewis, because Mr. Lewis had come a considerable distance to be present, and it would scarcely be fair to him to ask him to come another day. Mr. Lewis had nicely elucidated the subject, and the few remarks, which he himself had to bring before them, must have reference to two of the points which were very prominently brought forward, namely, as to whether the coal should be worked in angles, or by a square face. Mr. Lewis said, distinctly, not by angles, but by a square face, which was the best and simplest mode. The next point was with regard to ventilation. Mr. Lewis said the principle of the square face decidedly facilitated ventilation, and he in the next place clearly showed that no timber which might be inserted into workings by long-wall would answer the purpose of supporting the roof by itself. With regard to using timber chocks, instead of metal props, which Mr. Lewis said he employed, he would ask whether these chocks would not really meet the difficulty which Mr. Lewis said always attached itself to the face of a long-wall He would ask Mr. Lewis only one question more upon the whole case, and that was—what did he consider the shortest distance which the gateways should be from each other in point of econony, with respect to their being the means by which the coal is drawn from the face? and if Mr. Lewis had ever heard of a case, where, at the termination of the day's work, a moderate distance was driven, say, five or six yards into the solid face of the coal at each gateway, of sufficient width to get a right angle cutting, and so work the face in the direction of one gateway to the other? They had cases in each of these counties where such an operation was carried on very successfully. Perhaps Mr. Lewis would tell them whether he would admit that this might be advantageous, or would abide by his original principle, that the square face carried on was the best.

Mr. Lewis said, that being a resident in one of the Midland Counties, where nearly all the collieries worked upon the system of the long-wall, or a modification of it, and a member of an Institute located in the North of England, he had been induced to write the paper. Since writing it, they had increased the length of their face till now it was nearly a

To illustrate the discussion on Mr. Lewis' Paper on Long Wall working at Annesley.

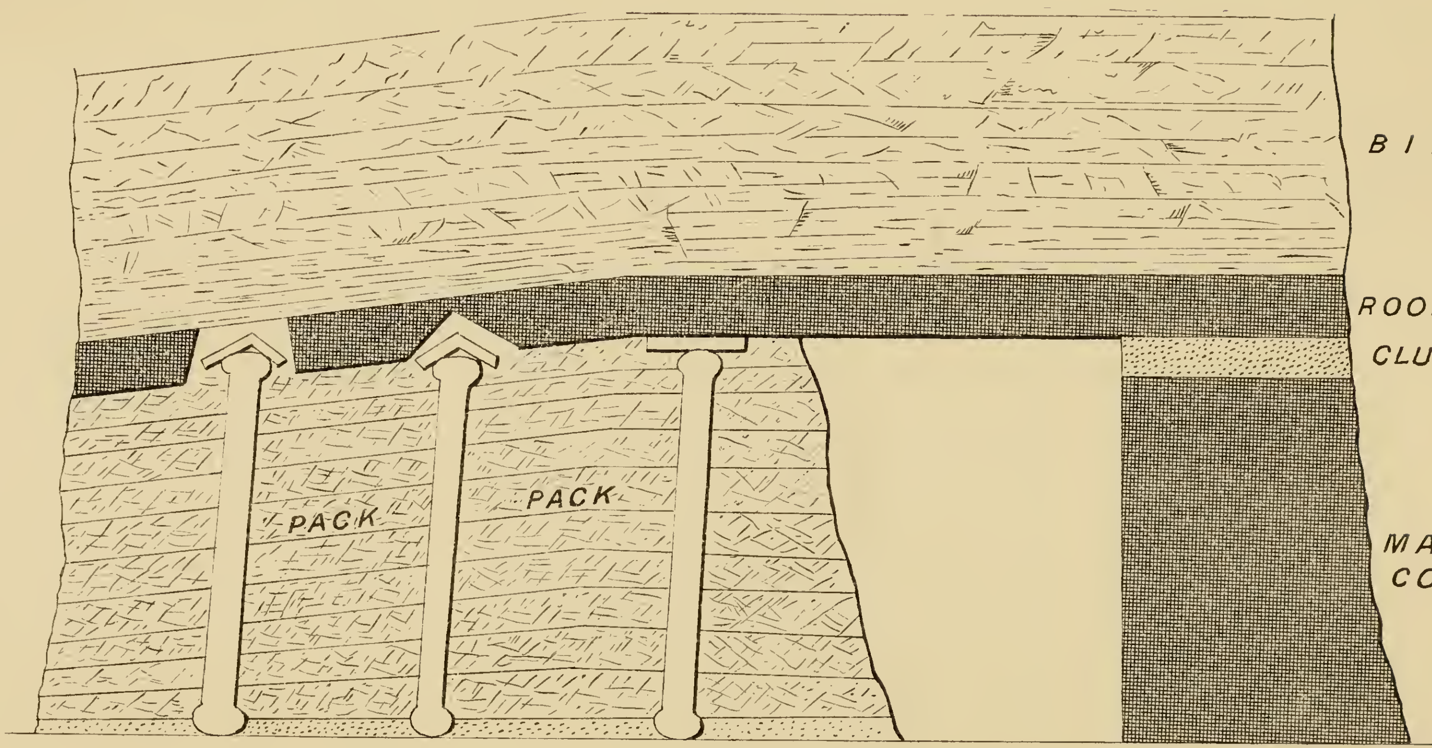
SECTION THROUGH GOAF AND MAIN ROAD.



Andw. Reid Newcastle

To illustrate the discussion on Mr. Lewis' Paper on Long Wall working at Annesley.

SIDE VIEW OF GATE ROAD ANNESLEY COLLIERY.



Andw Reid Newcastle

mile long—not exactly in a straight line, perhaps a little curved; but at all events there was not a single cutting in the whole length of the face. They knew they could work their coal properly in that manner; and he thought the proof was in the coal they realized. In the pit they realized 95 per cent. of large coal, and it was reduced to 80 per cent., because in the midland counties they had a system of making a number of sorts; and the 95 per cent. was more than any other system could produce, if tried at Annesley. And with regard to gates he still said that ripping was a very serious item They would see from Plate XXV. that ripping was only done in the principal gates; the others were cut off every hundred yards or so by means of a cross-gate. But supposing they continued the gates 200 yards before cutting off, the ripping would have to be done, and as this would cost 3s. a yard, each gate would cost something like £15 in ripping, which was entirely saved by the present system. A district generally consists of eight stalls, and putting in a new gate cost £1, so that opening out quite a new district cost eight times that amount. With regard to the President's observation about heading past the gate ends, as they termed them, he did not see any advantage to be derived from that; the coals were holed during the night, and in the morning the whole length of face was ready for getting off. They did not always go a certain distance in their holing, but sometimes 2, 3, or 4 feet, just as far as the weight had gone over the face of the stall. They found it did not answer their purpose to go past that.

Mr. Lewis, in answer to Mr. Crone, stated that the rise of the seam at Annesley is 1 in 60, and they work from the dip to the rise, although there are some dip workings as well; but the mile of face alluded to is on the rise.

Mr. Crone said, it would be very interesting if Mr. Lewis would give them the section showing the ripping and widths of the packs and gateways.

Mr. Lewis said, that it was shown in Plate XXV. which really represented the goaf as it was, and they would see from that how impossible it was for any gas to accumulate. As to the cast-iron props sinking into the roof, Plate No. XXVI. would illustrate this. They would see the first one as it was just set. The second prop had got a little weight, and was just entering into the "roof coal." The third prop was nearly through the roof coal; and, by the time it touched the bind, they found the weight had quietly settled on the packs beneath; the props are taken out as the face of the stall advances; the stones for packing are obtained from the fireclay overlying the coal.

Mr. Southern—The main weight goes into the goaf?

Mr. Lewis—The old gates are entirely closed by the refuse, and there is no open space at all. The clunch on the top of the coal, and the small quantity of roof coal brought in, entirely fills the goaf.

Mr. Bainbridge—The fact that Mr. Lewis can drive his gateroads more than 100 yards before making the cross way, partly explains why he is able to have a straight face for such a distance as a mile. Mr. Lewis, he thought, would admit that there were conditions under which the long-wall system was difficult to manage. He thought these conditions depended chiefly upon the character of the roof, which overlaid the seam for the first 20 or 30 yards. In his case there were 400 yards, and he (Mr. B.) had 200. He fancied that the adjacent overlying strata were very much heavier in the latter than in the former case, yet in the latter case they were able to get about 76 per cent. of round; and if they had no dirt band they would be able to get more.

Mr. Lewis—Certainly, 20 per cent. more than that is saved at Annesley; and he did not think Mr. Bainbridge was right in stating that he had a heavier weight in the first 20 or 30 yards of the overlying strata, than they had at Annesley. He said it was simply the fault of packing along the face, as it was the packs alone that protected the face; and where they came to make 20 per cent. more of slack, it was worth while trying a continuous face.

Mr. Bainbridge—The colliery in the case he alluded to, was working soft house coal; the coal at Annesley is hard steam coal.

Mr. Lewis did not read his paper with the idea that there was no other method of working by long-wall, or that his was the proper way, but simply to give the way they worked at Annesley, and the way they found it to act.

The President asked if he was correct in understanding that the line of their face was never by the cleat?

Mr. Lewis—Never by the cleat. When the colliery was first opened the workings were on the face, and by that method at least 50 per cent. of small coal was made, but by altering it and keeping it, half-end and face, 96 per cent. of large coal is realized.

The President asked the distance between the metal props, the face of the pack, and the face of the coal?

Mr. Lewis—They never had more than 6 or 7 feet from the first metal prop to the face of the coal, and never more than 6 or 7 feet from the pack to the face of the coal. There are roofs that will allow them further, and there are some places where the overlying clunch is 4 yards in thickness, and the distance between the end of the pack and the face of the coal has to be continually bared every four feet—a bar of timber running from the end of the pack to the face. If the face of the stall could be removed twice every day instead of once, the advantage would be greater, but they should be always moved every day.

Mr. Bainbridge did not make his remarks in disapproval of the system at Annesley. He considered it the most perfect and economical way of working coal to have a straight face a mile long when it could be accomplished.

Mr. A. L. Steavenson said, it was an extremely able and common sense paper; but he took exception to the statement that this long-wall was the only system which ought to be worked, and that all other systems were erroneous. He presumed he might be allowed to make an exception in the case of a perfectly clean seam (as at a colliery of which he had charge), with a very strong upset roof and small coals a desideratum (they were in fact crushing the coal to make it small). Mr. Lewis said his pressure did not exceed 1,500 lbs. on the square inch: how did he arrive at that pressure? Was it by calculating the weight of the superincumbent strata? Was it fair to take any such means of arriving at the pressure? As to there being no gas, he could quite understand that there was comparatively very little room for it, but still along the edge of the goaf there were always a great many cubic feet where the gases might lodge. He had seen the working of the long-wall in Nottinghamshire and other places, and he always saw room for the gas to lodge. No doubt there could be no very large quantity, but still in that respect he did not think the long-wall a success. Then, as to pillars dividing the districts, he quite agreed with Mr. Lewis, and thought them so much waste; and he also thought him right as to cutting off the stalls by cross roads, but he would like to ask whether he used powder, and whether he had much trouble with accidents from the coal falling back upon the men while getting out the corf as they called it.

Mr. Lewis certainly thought the long-wall adapted to many seams where it is not adopted at the present day. The enormous amount of heading and cutting that had to be done in opening out a colliery by bord and pillar, was entirely saved in long-wall. With regard to the weight, he took the superincumbent strata as exerting a pressure of 1 pound for every foot in depth, which at 1,500 feet would give 1,500 pounds to the square inch; and with regard to Mr. Steavenson's observation, that gas might run along the edge of the goaf in long-wall working, he could only say that at Annesley there was not the slightest room for gas to lodge along the face; and considering that for each 300 yards of face, there were from 12 to 15 thousand cubic feet of air per minute, he thought every member would agree with him that it did not give it much chance to accumulate. They sometimes had accidents from holing, but seldom any fatal ones; it would be seen that much depended upon the supervision of the deputies, as well as on the care of the men themselves, as to whether they were numerous or scarce. The strata overlying the coal acted as a lever, and as the coal stood above three or four hours after it was holed, it simply required the sprags knocking out, and it was seldom they wanted powder.

Mr. Cooper asked whether the 95 per cent. meant the coal filled and actually sent out of the pits? He knew that in working these long-wall places they were not very particular in leaving coal in the gob. Another important question was the cost of getting the coal on this method.

Mr. Lewis said, that in the Midland Counties they paid so much per foot per acre; and as the men were paid by the ton, it was an easy matter, after the half-yearly survey, to get the exact quantity realized per acre.

Mr. A. L. Steavenson hoped Mr. Lewis did not think he spoke in antagonism to him. He thought it a very excellent paper and a very excellent system; but he happened to be down a pit in the neighbourhood of Derby, a short time ago, where they worked the long-wall, and they used candles, and without thinking, he raised his candle rather too high, and was instantly told to keep it down, as it was by no means safe to raise it to such a height.

Mr. Lewis, in reply to Mr. Southern, stated that they made half coal and half slack when the line of face was in the cleat; but by altering it to half end and face, they made 96 per cent. of large coal.

Mr. Southern could confirm that from his own experience; because at a large colliery that he had the management of some time ago, they found a very considerable difference by cutting the cleat.

The President—Can the air be conducted along by the face properly, so as to keep it clear?

Mr. Lewis—Of course there are very often obstructions; but when this is the case, the air can slip down one gate and up the next.

The President—Are any means taken to keep the goaves left behind clear of gas?

Mr. Lewis—There is no open space in the goaf at all; the clunch, and what small coal is made, completely fill it.

The President quite understood Mr. Lewis to mean the pack was complete. But did any gas accumulate in the gateways after they were abandoned?

Mr. Lewis—No; as they are always filled by taking in the dirt made by ripping the principal gates.

Mr. Crone said with regard to the use of metal props, very much depended on the nature of the roof to be supported; and Mr. Lewis' position was very favourable for that purpose—the props sunk into the soft coal at the top, and were easily removed afterwards; but, if sunk into a hard stone, they became so firmly fixed as to be almost immoveable. It was in such cases that the chocks used in the North of England were found so useful.

Mr. Lewis said the metal props had been in use something like four years, and they never had a single prop broken. The cost was much less than others, and they never got fast in the pack. They were set away a short distance.

Mr. Crone thought, as to the long-wall system, that very much would depend upon the kind of seam they had to work. If they had to contend with a large amount of stone band, or of inferior coal, all of which had to be cast back, that of course formed a packing which they did not get out of a large and clean seam of coal; and, he thought it would be found in practice, that, where they had a clean good seam of sufficient height, it would work more easily, and at less expense, by the ordinary way of board and pillar than by the long-wall. He thought it resolved itself into this: that with a thin seam, and a lot of inferior material to contend with, the long-wall system could be easily adopted; but where the coal was clean, and nothing available to form the pack walls, with the exception of the stone wrought down in the gateroads, sufficient stone for the support of the goaf would not be found, and the consequence would be, that the stone to make those packs in the goaf would have to be sought, which would be a very expensive process indeed.

Mr. Lewis said that in the Midland Counties it was a question of large coal. Much of the coal in the North of England would simply sell for slack; so that the system there pursued would not answer elsewhere, but the long-wall system would answer in many seams now worked by other methods.

Mr. Crone said Mr. Lewis was mistaken in supposing they did not want large coals. What Mr. Steavenson had spoken about was only as to gas and coking coal; but in the steam coal districts large coal was a most important consideration, and they would only be too glad to adopt any system that would cause the yield of large coal to be increased. No doubt Mr. Lewis was aware that small seams were coming into play, which required a considerable amount of stone to be removed for height to work, and that these seams, and those containing bands, might have the long-wall applied to them; he thought the system would come into much more extensive use in the north of England than hitherto. As yet they had always worked coals in good seams, and had not the necessity of having a goaf immediately behind them to pack in their refuse.

Mr. Lewis thought that any system by which heading could be dispensed with, whether large coal was in question or not, must be more economical than a system where the coal was divided into pillars.

Mr. Crone said he had a long face on a thin seam; but, unfortunately, the rise of the seam was about 5 inches to the yard, and he had found very great difficulty, indeed, in working the long-wall at that rise.

The President—Could it not be worked half and half, and the face kept edgeways in the open?

Mr. Crone said it could not be done. The tubs could not be pushed up.

The President—But the gateways would be on the same line as the level. He had seen that in the north they had two or three instances of such seams, and they never attempted to pursue them up to the full rise; they simply put gateways in-bye: here they have not so many gateways as in the Midland Counties, only one in 200 yards.

Mr. Crone stated that he worked some coal at one in four by the long-wall. In such cases they had a balance weight or self-acting incline. He found very great difficulty in forming the gateways, because, every gateway had to be an incline, and that, of course, required the gateway to be of considerable width, and when the gateways had to be enlarged—"ripped"—by taking down the stone or taking up the bottom, it must either come down the incline to be sent to bank, or dragged at a considerable expense to the rise and packed into the goaf. They could not gain the full advantage from the goaf to stow in or form the packing in a satisfactory manner where the seam had such a heavy rise. Every coal-seam had peculiarities of its own, which would have to be examined, in adopting the system and direction of working, whether on end, or parallel to the line of cleat; and not only the seam, but the overlying stone above, he thought, would be found safer, and the coal worked larger, when the line of long-wall face was at right angles to the "facings" of the stone overlying the seam, as the stone, in that case, was more likely to stand firmer at the face and droop gradually down behind, than if driven parallel to the stone facings, when it would be more likely to slip out between the facings, should any excessive pressure come upon it, or throw unusual weight upon the coal face, thus causing injury by crushing the coal. Mr. Lewis had worked coal rising one in three, and found no difficulty, as all places were taken parallel to the levels.

Mr. Burn said, he was in Nottinghamshire, a short time ago, and through the kindness of Mr. Lewis, was allowed to go down the Annesley Pit, and he certainly was much pleased with the system carried out there; he considered it the best long-wall pit he had ever seen.

The President proposed a cordial vote of thanks to Mr. Lewis, for coming all the way from the centre of England to read a paper for the edification of the northern members. He, himself, felt very much obliged to Mr. Lewis, as the subject was one in which he felt greatly interested.

Mr. Lewis would be happy to show the system to any member of the Institute, and they would be able to judge of the relative merits by actual observation.

The President said they were very much indebted to Mr. Lewis, and he must not be surprised if they took advantage of his offer.

The meeting then separated.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, APRIL 6, 1872, IN THE LECTURE ROOM OF THE LITERARY AND PHILOSOPHICAL SOCIETY.

E. F. BOYD, Esq., President of the Institute, in the Chair.

The Assistant Secretary read the minutes of the last meeting and of the Council meetings.

The President was glad to inform the meeting that the gentlemen of Glasgow, who entertained them so handsomely last year, had accepted their invitation to attend a joint meeting here in July, and had given notice for the preparation of papers to be read on that occasion, and he thought there was every prospect of the meeting being a very interesting one. No answer had yet been received from the Lancashire and Cheshire Coal Trade Association gentlemen.

The following gentlemen were elected:—

Members.

Mr. Thomas Whitelaw, Shields and Dalzell Collieries, Motherwell.
Mr. Thomas Joseph, Ty Draw, near Pontypridd, South Wales.
Mr. Fred. W. Shallis, Bulman Village, Newcastle-on-Tyne.
Mr. Thomas Johnston, Widdrington Colliery, Acklington.
Mr. Edward Joicey, Coal Owner, Newcastle-on-Tyne.
Mr. John Patton, Westoe, South Shields.
Mr. John Hilton Ridley, Messrs. R. and W. Hawthorn's, Newcastle.
Mr. William James Johnson, W.B. Lead Works, Allendale.

Students.

Mr. J. J. Hedley, Medomsley, Burnopfield.
Mr. David Joseph, Ty Draw, near Pontypridd, South Wales.

The following gentlemen were nominated for election at the May meeting:—

MEMBERS.

Mr. GEORGE WILLIAM HICK, Mechanical Engineer, 17, Blenheim Terrace, Leeds.

Mr. CHARLES G. GREY, Dilston, Northumberland.

Mr. MATTHEW ROBSON, Coppa Colliery, near Mold, Flintshire.

Mr. LLEWELYN LLEWELYN, Aberaman, Aberdare, South Wales.

Mr. G. W. WILKINSON, Pensher Colliery, Fence Houses.

STUDENT.

Mr. J. J. PARLAND, Mining Engineer, Burnopfield.

Mr. SANDERSON then read a paper "On the Use of Air-Vessels in Pumping Engines and the Means of Replenishing them."

ON THE USE OF AIR-VESSELS IN PUMPING ENGINES AND THE MEANS OF REPLENISHING THEM.

By R. BURDON SANDERSON.

Before proceeding to the immediate subject of this paper, that of Air-vessels, the writer would wish to state forcibly that there is no one point that requires the constant attention of the engineer having practically to deal with water on a large scale and under heavy pressure more than the action of air within his apparatus. Of all enemies that he has to contend with it is one of the greatest. It is capable of arresting the flow of water under the heaviest pressure and in the largest main, and of smashing up the strongest available castings. At the same time in its proper place it is of the greatest use—literally a good servant but a bad master. If it is allowed to accumulate in a rising bend, it soon forms an effective valve, and gradually shuts off the flow however large in the pipe, and if in charging a long main under pressure, the greatest pains are not taken, in opening the sludges and the air-valves, on the line, to keep the air from accumulating in any spot between either a dead end or two columns of water, the fracture of the main, at one, if not at two, places at the same time may be almost guaranteed. The writer has known from this cause two breaks in a 24-inch main at five miles distant from each other at one moment, and is not certain whether it has not happened more than once. It is possible that the air acts by allowing the column of water the opportunity of giving a ram blow of a long stroke driven forward with all the force of a cushion of air previously compressed behind it. What may be the possible strength of this blow it is almost impracticable to calculate. It is, however, a subject deserving of the closest attention, as it may lead even to such a catastrophe as the fracture of an engine beam.

The diagram in Plate XXVII. is, it is needless to say, an imaginary one, and represents the plunger of a pump P; on one side a rising main, R M; on the other, and between them, an air-vessel, A V, with the usual clacks, &c., and suction pipe. The cross lines on the plunger-case, air-vessel, and rising main represent equal cubical contents, as do also the half of these cross lines. It will be seen that the air-vessel is made to contain five times the whole and ten times the half of the cubical contents of the stroke of the plunger.

Imagine the engine set agoing, the water standing at the level shown A B, with the exception of the plunger case, which is charged full up to the plunger itself; and, suppose the air-vessel shut off; the piston descends, and its first operation is to overcome the *vis inertiæ* in the water, trifling under light pressure, but very large when the rising main is fully charged. The water rises by the descent of the piston (the diameter of the plunger and the rising main being supposed equal) a space exactly equal to the length of the plunger's stroke (in the diagram supposed to be 9 feet). The column would come to a rest provided it possessed no *vis viva* and the upper clack closed instantly. Neither of these things happen. The water possesses an amount of *vis viva* not exhausted, remaining over from that communicated by the piston, in first setting the column in motion from a stationary state, and the clack, in its ordinary form, stands open for some appreciable time; consequently, the column of water falls back a certain space, with more or less force added to its statical pressure, on to the clack. But open the air-vessel, and a different state of things takes place. Suppose the head of water on the pumps, at the level indicated, equal to 50 fathoms, or 300 feet—equal practically to nine atmospheres; to which, from the air-vessel and the air in it being free at its upper portion from atmospheric pressure, another atmosphere must be added, making ten atmospheres, by which the air at the bottom of the air-vessel is retained in its position, balancing the column in the rising main. Let the plunger be again at the top, and bring it down upon the water in its case to the bottom of its stroke, the water now rises but half the length of the stroke in the rising main, the other half having passed into the air-vessel.* The piston rises and the upper clack shuts, but the column of water in the rising main, though it may lose a little pressure in the closing of the clack, still continues its upward motion with only slightly decreased velocity, this being maintained by the discharge again of the half charge of water taken in by the air-vessel in consequence of the relief from the pressure which forced it in, the air-vessel acting almost like a second engine in alternation with the first. At the end, therefore, of the compound stroke (the up and down) of the piston, and not at the end of

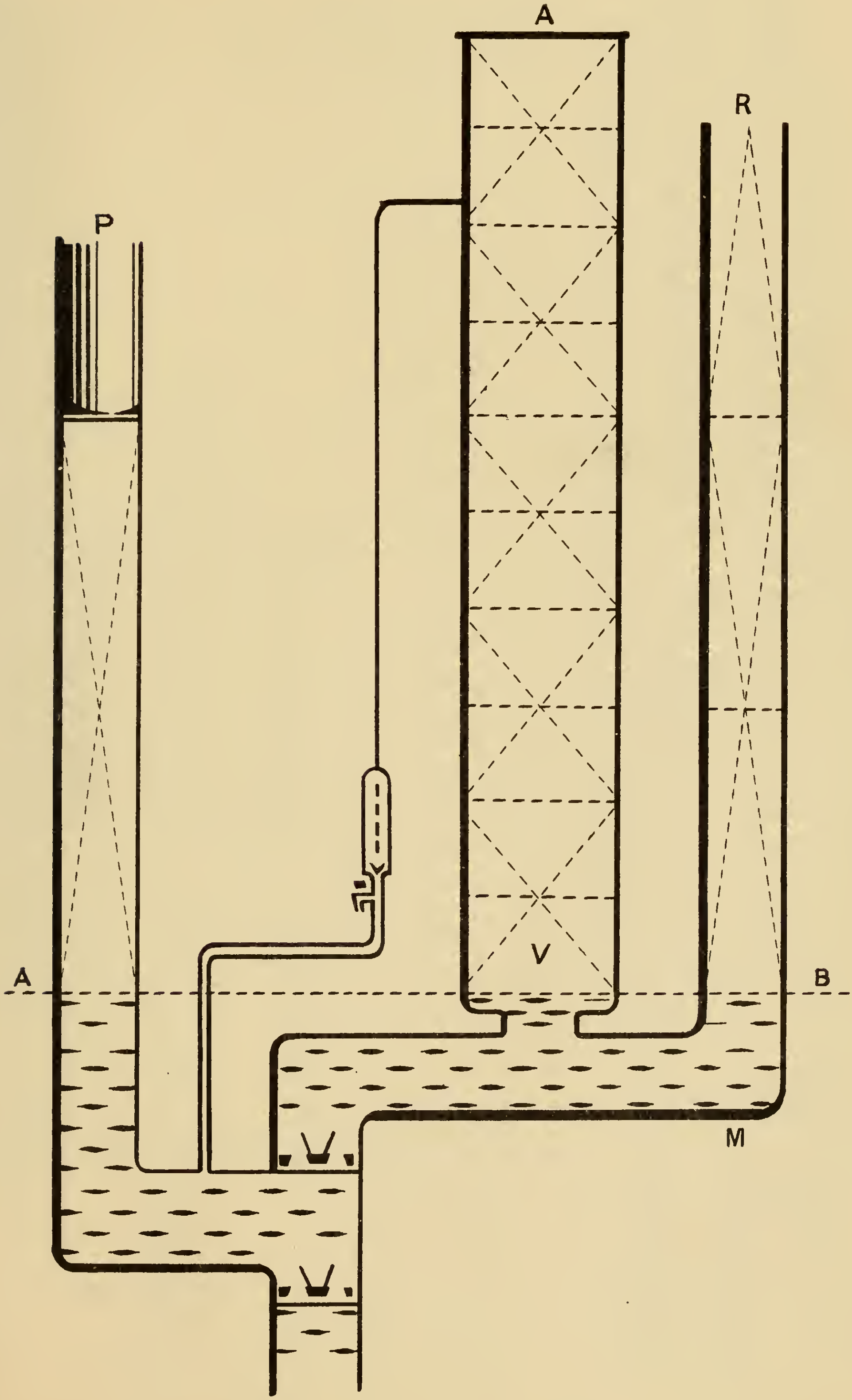
* That this is the case is shown in practice, by a glass gauge tube, outside the air-vessel, indicating the height of water inside.

the down stroke, as in the first case, is the water in the rising main found to have made a progress equal to the length of the plunger. Now consider what is the effect on the pressure, and what are the limits between which this oscillates. Returning to the diagram, and taking the lowest pressure as equal to 300 feet (the air-vessel standing charged at this, when at the line A B), so soon as half the piston stroke charge of water is forced up into it, this half, being, as shown, equal to a tenth of its contents, the air in it, which occupied 10 spaces, now occupies nine, and according to the well-known law, the tension increases inversely—that is to say, in the proportion as 9 : 10 : : 300 to the new pressure, namely, 333, the difference 33 feet representing the limits between the maximum and minimum pressure on the rising main. Suppose another state of things: leave 300 feet still to represent the pressure on the air in the lower surface of the air-vessel; let this last be only charged down as far as the second line from the top; if it were possible to force one-half of the plunger stroke contents into it, the air would be compressed to the first line from the top, and the pressure would become at the bottom of the stroke precisely doubled, as will be seen by looking at the diagrams, and the head would be increased as 1 to 2, namely, from 300 to 600 feet. This, however, is quite impossible, and the water would relieve itself by simply rising in the air-vessel, say half a division, representing one-quarter of the piston stroke contents, and the remaining three-quarters passing up the rising main, and so approaching the state of things where there is no air-vessel at all: the variation would then represent a proportion of 3 to 4, or 300 to 400. The writer, in these illustrations has disregarded for simplicity's sake the difference between the pressure of the column of water at rest in the rising main and the mean pressure when in motion, which is of course greater. From what has been stated it is clear that the cubical contents of the air-vessel must be made sufficiently great, and that it must also be fully charged. An air-vessel of much less than a minimum of five times the cubical contents of the stroke of the plunger would not be large enough to do much good; nor would this do if not fully charged at a pressure equal to the column of the rising main. If for example the air-vessel was standing filled with air at its ordinary density, and the column of the rising main at a head of 300 feet was suddenly put on, the air inside would be forced into one-tenth of its previous space, and an air-cushion would be formed of no practical utility, if not fraught with considerable absolute danger. It becomes necessary, therefore, to devise means to charge and to keep charged the air-vessel. For this, different means are adopted, such as the use of a special donkey air-pump, or a small pump drawn by the engine, or a sniff-cock under the plunger case. None of these, however, equal in simplicity, elegance, and efficiency, the arrangement now described, and of which diagrams are given. Plate XXVIII., Fig. No. 1, gives a section of the apparatus. It consists of a cylindrical case A, like a miniature air-vessel, below which, and leading from it to the portion of the pump-work below the bottom of the plunger-case D, Fig. 2, is a small pipe B. From the top of it another small pipe C leads into the upper portion of the air-vessel. On the floor of the small cylinder, and at the top of the pipe leading from the bottom of the plunger is a small valve D, opening upwards, and below the small cylinder on the right hand and opening out of the lower pipe is a sniff-cock E, opening upwards and inwards with a set-screw into it so as to adjust the lift of its valve or to close it entirely as required. The action of it is this—the lower pipe is kept filled with water up to the level of the sniff-cock; as the plunger rises it draws this water down into the pipe just as far as the ingress of the air through the sniff-cock will permit; in the down stroke of the plunger the water is forced up again and the air before it; the sniff-cock closes, the valves in the small cylinder open, and the air is forced into this latter and through the upper pipe into the air-vessel. The quantity of air admitted is regulated, as before stated, by the set-screw of the sniff-cock according to the requirements. The author wishes to correct a statement he made during the last discussion, that one of the air-vessels on the Water Company's engine at Newburn lost 1 inch of air at each stroke. It was so far true that it did so at the time in question, but it was in consequence of a leak in the joints of the air-vessel, which was afterwards remedied, and it is now found that a small quantity of air only is required in practice through the apparatus to keep the air-vessels charged. Plate XXIX., Fig. 1, shows the actual arrangement of the air-vessel and air-charger relative to the plunger and delivery mains at present at work at the Gateshead Pumping Station of the Newcastle and Gateshead Water Company. The question now arises, of what use are these suggestions in colliery practice, as it would be in most cases practically impossible to apply in a shaft air-vessels of the size used aboveground? The writer would answer—by making a suggestion which the resident engineer of the Water Company, Mr. J. R. Forster, who is very conversant with shaft work, thinks quite practicable. Plate XXVIII., Fig. 2. Suppose, for illustration, that it is proposed to adopt the arrangement under circumstances in which an 18 inch set would be used; at the lowest joint, from which the 18 inch common pumps would take their origin, an enlarging piece F is inserted, and upon this as many lengths of 24 inch common pumps as will make up 36 feet in length. Upon this, again, a contracting piece G is placed, reducing the internal diameter to 14 inches from which rises a 14 inch instead of an 18 inch set. Between this last joint, and bolted in with it so that it may be packed from the outside, is inserted a collar H of 12 inches internal diameter, from which is suspended a sheet iron cylinder I of 12 inches internal diameter, also reaching to nearly the bottom of the 24 inch common pumps. This last may be made of $\frac{1}{4}$ inch plate iron, provided it is constructed thoroughly air-tight, the pressure on both sides of the plate iron being equal. Taking these proportions, it will be found that, assuming the set is worked by a 17 inch pump K of 9 feet stroke, the contents of the space between the inner cylinder and the 24 inch common pumps, forming the air-vessel, will be five times the contents of the stroke of the plunger, 24 inches × 24 inches × ·7853, less 13 inches × 13 × ·7853 × 36 feet, being equal to 84 feet, or thereabouts, and 17 inches × 17 inches × ·7853 × 9 feet length of plunger stroke, are equal to 14 feet, or thereabouts. This makes the contents of the air-vessel the proportion of 10 times the cubic contents of half the plunger stroke, the minimum that should be used. But it may be objected, why should the 18 inch common pumps be reduced to 14 inches? For this reason, that, while in the arrangement proposed, it has been shown that the water column would be in motion during nearly the whole of its time, in the present it is so during only *half;* consequently, in all calculations as to size of pumps, consideration must not be had as to what size of set is required to lift a given quantity of water per minute a given height, but what size is required to do this in half that time: and this is probably the reason that, in colliery practice, a main of double the diameter is used to convey a given quantity of water a given height to the top of a shaft to what would be used to convey the same quantity of water the same height for a distance of five or six miles in water works. In the diagram, however, the area of the proposed rising main is not one-half, but about three-fifths the diameter of that superseded. If the arrangement succeeds, as it is anticipated it must, the following would be the advantages. In the first place, an absence of loss of power by the excess required to overcome the *vis inertiæ* in a column of water alternately at motion and at rest, an excess mischievously returned again by the falling of the column upon the upper clack after the end of the down stroke of the plunger; secondly, these shocks, so mischievous and dangerous, are, in a great measure, obviated; and, in the third place, a much lighter rising set is required, and a lighter column by one-third, at least, of water in this set has to be supported in the shaft. The writer may mention, before concluding, an incident which occurred in connection with some experiments which he made with Mr. Forster by way of verification, a few days since. At the end of one of them, and when the plunger had arrived at the top of the stroke and the pressure was at the lowest, a very violent series of rapid oscillations took place, of 100 feet or more in extent in the pressure gauge, exactly similar to what is described in some of the diagrams in Mr. Bainbridge's and Mr. Hall's papers. The engineman, by going outside, discovered that a portion of the packing of one of the joints immediately above the suction clack had been blown out, and that air was being drawn in which had accumulated under the plunger or under the upper clack, or both. There were no means of remedying it at the moment, but it has been since done to the entire removal of the whole oscillation. The engine was not in service or it would have been necessary to have stopped it until the damage was repaired; all such vibrations indicate a state of things which must be carefully watched, and cannot be suffered to continue without mischief occurring. The writer is inclined to think that the sort of accident related by Mr. Bainbridge, may have occurred in the same way. It is very difficult to make the faces of such castings as described by him perfectly water-tight, still more perfectly air-tight; and if a small quantity of air was drawn in at each stroke in the manner just described as having actually occurred, a quantity sufficient might collect there just underneath the bucket of the pump, sufficient to create very great mischief, causing such vibratory blows as are indicated by the oscillations of the pressure gauge. Heavy blows, not in themselves sufficient to break cast iron, may become so when accompanied with a coincident state of rapid vibration in the iron itself.

Fig. 2, Plate XXIX., is a diagram intended to illustrate the use of the air-vessel in modifying the variation in pressure during each stroke of the pumps, and was taken from an experiment made with one of the Newburn engines, the plunger of which is 34 inches in diameter, and the stroke 10 feet. The letters T and B represent the top and bottom of the stroke of the plunger, and the 10 parallel spaces 1 to 10 the 10 feet of the same. The upper crossed black lines A B show the rise and fall of the water line in the air-vessel as indicated by an external glass tube. The longest of the lower crossed lines C D shows the variation of pressure when the air-vessel is merely charged with its usual contents of atmospheric air compressed by the column of water, in the experiment equal to a head of about 200 feet, into a proportional small bulk, and the shorter of the crossed lines E F the variation when properly and fully charged down. The air-vessel lines correspond to this latter. It will be noticed that the limit from minimum to maximum is 120 feet in the former and 40 feet in the latter case, and it will be observed that the minimum pressure X is reached in all the examples a little after the plunger stroke commences rising, possibly from the re-oscillation not having been completed when the plunger commences its stroke; and it will be further noticed that the maximum pressure Y is reached in both cases, before the plunger completes its down stroke. This arises from the engine, for obvious reasons, being so geared as to complete the last foot and a half of its stroke at a very reduced speed.

A paper "On Pumping Engines, Paper No. 2," was then read by Mr. W. Waller.

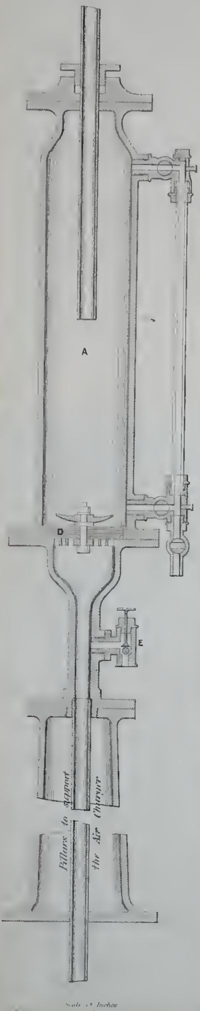
Diagram to illustrate Mr. Burdon Sanderson's paper; On the Use of Air Vessels in Pumping Engines, and the means of replenishing them.



Andw. Reid Newcastle

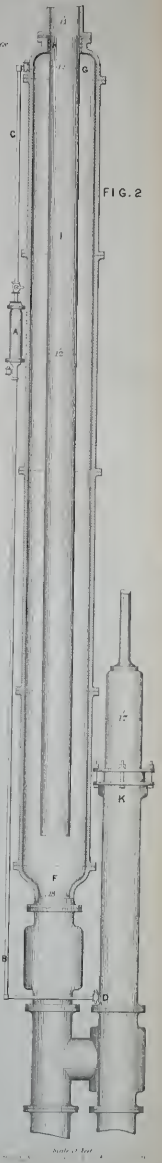
To illustrate Mr. Buxton Sanderson's paper on the use of Air Vessels in Pumping Engines and the means of replenishing them

FIG. 1



Proposed Arrangement of Ascending Main with Air Vessel and Air Charger attached

FIG. 2



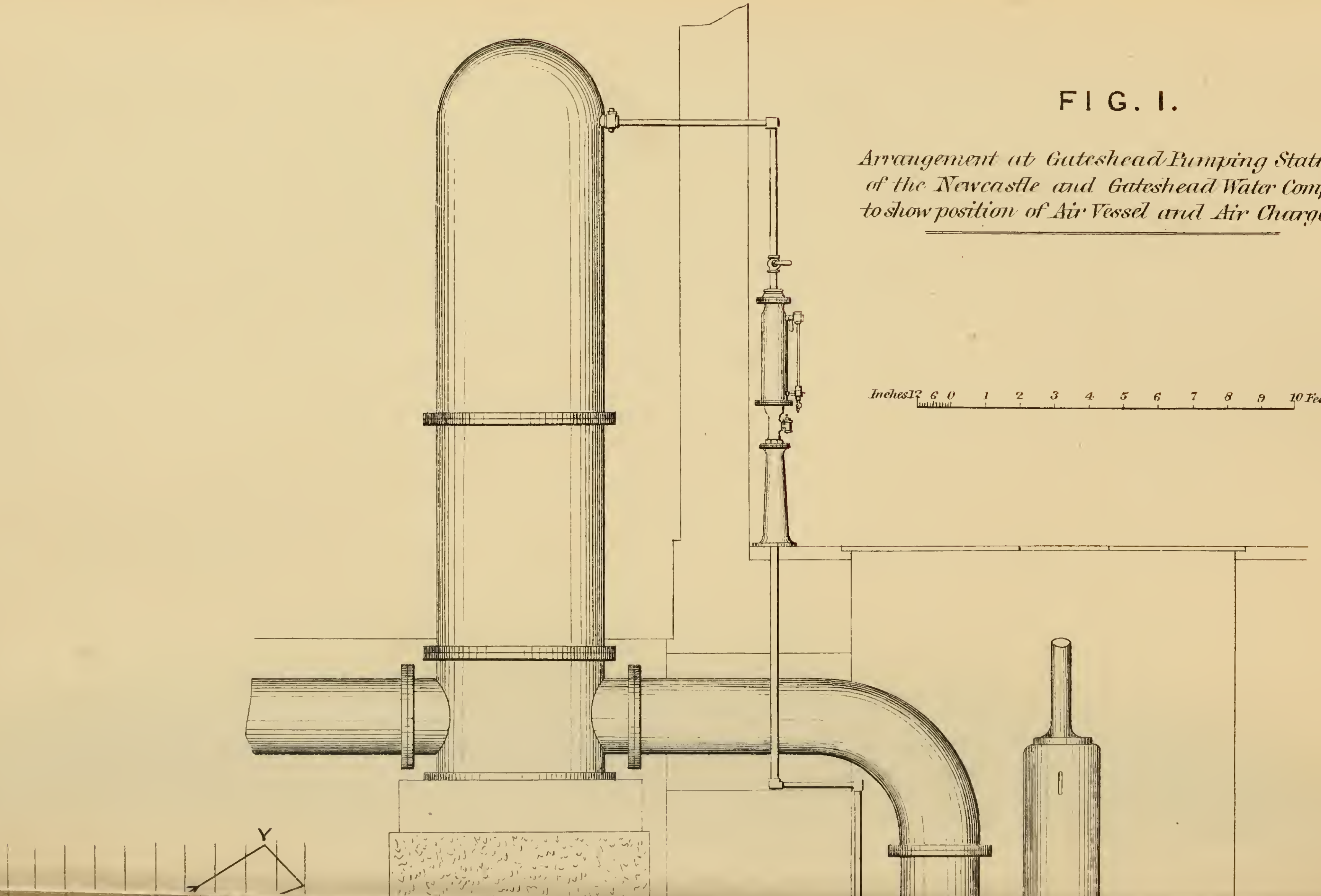
Scale of Inches

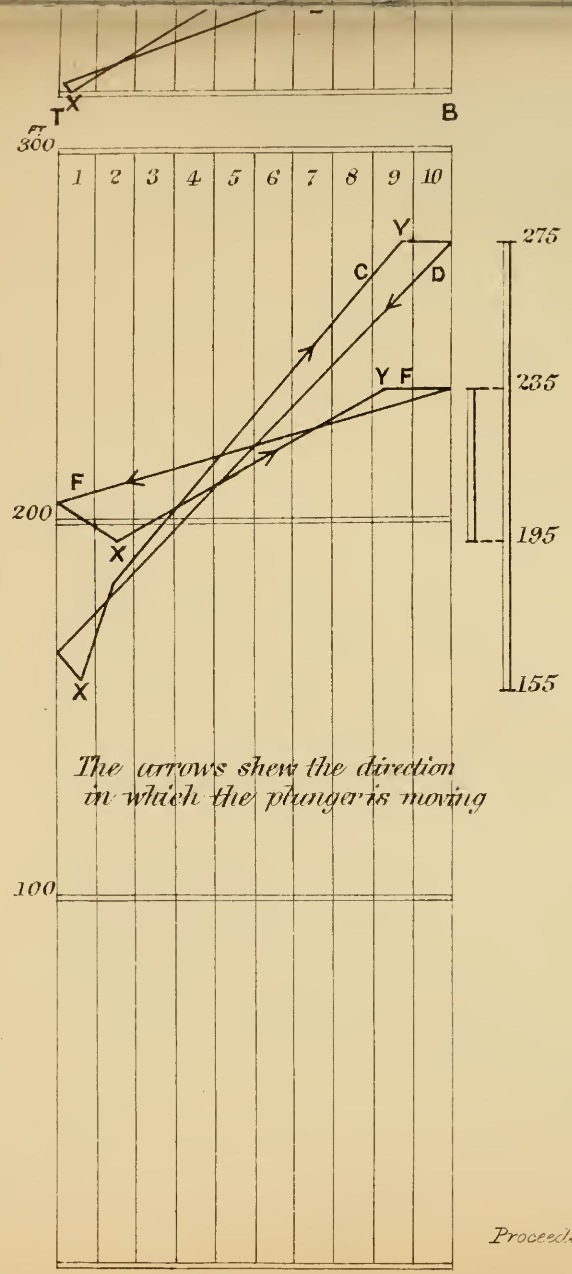
Scale of Feet

To illustrate Mr. Burdon Sanderson's paper, on the use of Air Vessels in Pumping Engines and the means of replenishing them.

FIG. I.

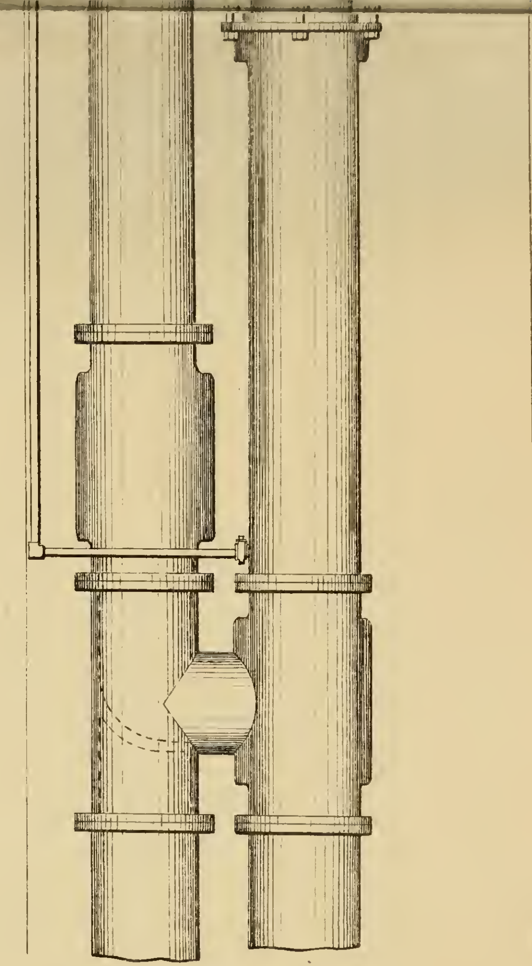
Arrangement at Gateshead Pumping Station of the Newcastle and Gateshead Water Company to show position of Air Vessel and Air Charger.





T
X
B
FT 300
1
2
3
4
5
6
7
8
9
10
Y
C
D
Y F
F
200
X
X
275
235
195
155
The arrows shew the direction in which the plunger is moving
100

FIG. 2.



ON PUMPING WATER.—PAPER No. 2.

By WILLIAM WALLER.

In the former paper on "Pumping Engines," given in the Proceedings of August, 1867, the main consideration was given to the best kind of engine for the purpose, in reply to an enquiry put by one of the members.

In working out the results, the standard of one million foot pounds was adopted, at the suggestion of Mr. Bunning, as a tangible figure, well calculated to supersede the various standards in use, such as 1000, or 1,000,000 gallons; but as subsequent papers have not retained this, it is not used here, for the double reason, that it is not used in the documents quoted, and that it may have been found objectionable.

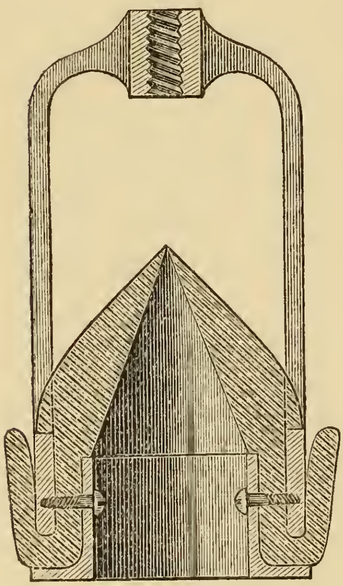
The process of pumping is supposed to be too well understood to need any explanation, and being governed by simple known laws, would render any general remarks upon it superfluous; but there were some assertions in the late discussion which invite remark and explanation, and must form the apology for a few sentences.

To illustrate one point, an anecdote, which came within the knowledge of the writer, may be excused. An engineer of considerable experience, the head of an extensive firm, turning out perhaps the greatest number of engines in the United Kingdom, had a common hand pump in the corner of his yard, so placed that there was very little room for the handle of his pump, which was provided with a large knob on the end of a straight arm. Finding the pump work stiffly, he had the handle taken off and sent to the works, where four feet were added to the length and the handle curled so as still not to touch the wall; after which he declared, and still believes, that he had eased the labour by lengthening the lever. This shows two things; first, that there are engineers who are not thoroughly skilled in these simple matters; and secondly, the value of balancing the dead weight.

To raise the question of the process of pumping, two main points present themselves for consideration. What draws the water into the pump? and what closes the valves? and to consider these, we will suppose that the clack is not "drowned," but is clear of the water. In the late discussion, it would appear that much confusion arose for want of a definite understanding as to the position of the water, for where the plunger is below the water level the water will rush in and fill the space left by its withdrawal and the consequent partial vacuum formed, owing to the head of water and atmospheric pressure; but where the pump barrel is some distance above the water, there cannot be any spontaneous rush of water into the pump barrel, it must be drawn, and here arises the first question—What draws the water?

In the first place the air in the pump and suction pipe has to be pumped, drawn, and attenuated until a partial vacuum is formed; the water then enters and fills so much of the space until it is in balance, or until the atmospheric pressure on the water is nearly regained by the reduction of the air space—so again repeatedly till nearly all of the air has been discharged by the return strokes of the plunger, and the water is acted upon by the plunger; but it must be borne in mind that as a perfect vacuum is unattainable, there must be always some air under the plunger alternately attenuated and compressed, and kept up by leakage at the gland and joints (which will account for the difference between the theoretical and actual delivery of the pump), besides the expansion and compression of the air contained in the water itself. Water then is drawn by the action of the pump and the exhaustion of air from the pipes, and does not flow spontaneously.

What closes the valves? The expansion of the air contained in the barrel and the return movement of the column of water together carry with them the valve covers, and disprove the theory of the *vis viva* giving a constant delivery from the top.



To assume a perfect pump would be also to suppose a perfect vacuum, the absence of any spring of the pump rods, of any motion in the pumps themselves, and of other evils which have to be contended with, and which must be all remedied before we can suppose perfection.

The necessary opening for a valve or bucket is much less than is generally supposed, and hence a greater amount of percussive force is allowed. The glass barrel pump, kindly lent by Messrs. Perreaux and Co., of London, fitted with their patent valve in both bucket and clack, will show how little opening is really required; the valves open more or less as required, and do not readily gag when passing pieces of stick or coal. (See illustration.)

In the action of the steam engine and pump there is a difference from that of a hand pump, which may be suddenly put in motion and as suddenly arrested; on the other hand, the steam, being cut off before the stroke is completed, allows a gradual reduction of speed until the eduction valve is opened and the motive power discharged, so motion is arrested and reversed; the beginning of the stroke being also gradual. That the suction of the water is entirely dependent upon the motion of the plunger, can be proved by both hand and power pumps; for where a stroke is made suddenly and quickly the quantity of water delivered is less than where a steady motion is maintained. Taking the quantity delivered by pumps at various speeds, a certain point will be found where the best result is obtained, and this is believed to be about 100 feet of plunger per minute as the maximum. In the simple illustration given by Professor Herschel, of a penny placed loosely on the hand, and the hand being raised and suddenly stopped, by striking it against a fixed object, the penny will leave the hand more or less according to the speed at which it was moving at the moment of stoppage; and this example will hold good in the case of a hand pump, to a certain extent. But apply this example a little more closely to the case of a pump; let the hand be moist and the penny pressed to it so as to cause it to adhere to the skin by the absence of air between the surfaces, and then see what must be the velocity at which contact is broken by sudden stoppage. This is more nearly the case in pumping, for there can be no air upon the bucket, and the example is only applicable in the case of a bucket lift.

It may be urged that the suction pipe being less in diameter than the working barrel, the velocity of the water passing through it will be greater than in the upper part of the set of pumps, and that this will give a supply through the clack after the pump-bucket or plunger has stopped; but if the velocity be greater, so will the friction be; and where there are different diameters, the motion of the whole will be equal *pro rata* as to quantity, for any *vis viva* that may exist will have to be given out under a considerable head of water, and so the greater velocity of the smaller stream is lost in the larger bulk of the upper pipes. To assume a speed of five to six feet per second in water following a plunger moving at only 100 feet per minute, would be to assert that the effect should be greater than the cause in the ratio of nearly six to one.

Pumps have been designed to keep the water in continuous motion in the suction pipes and delivery pipes—as the centrifugal pump, the chain pump, and the three-throw pump, but in each of these there is a bucket, or its equivalent, in constant action.

As the question has been raised as to the comparison between the theoretical and actual delivery of pumps it will be interesting to know what has been proved to be the case, and to test other results given by the same enquiry. With this view the following tables of the engines and pumps, at the Liverpool Corporation Waterworks, are given, taken from a report made by Messrs. Simpson and Newlands, in 1849:—

TABLE No. 1.

Station.	Number of Engine.	Engines.			Pumps.			Boilers.				
		Description.	Cylinder.		Description.	Diameter.	Stroke.	Number.	Length.	Width.	Depth.	Pressure.
			Diameter.	Stroke.								
			In.	Ft. In.		In.	In.		Ft. In.	Ft. In.	Ft. In.	Lbs.
Bootle	1	Double-acting crank	34	6 0	* Double-acting	16½	45					
Do.	2	Do.	31¼	6 0	* Do.	16½	45	5	25 0	6 1	7 3	4½
Do.	3	Do.	34	6 0	* Do.	18¼	48					
Everton	1	Double-acting crank	14¼	6 0	Double-acting	15⅝	48	2	19 0	5 0	Diamtr	35
B. Bush	1	Single-acting..	38	7 0	Single-acting..	12¼	74	1	18 4	8 0	8 0	6
								..	18 0	8 0	8 0	6
Soho	1	Double-acting crank	30	6 1	† Double-acting	8⅝	47	2	22 0	6 10	8 6	6
					Single-acting..	9¾	57					
Hotham St.	1	Double-acting crank	27	5 3	† Double-acting	8⅝	40½	1	18 6	6 0	6 0	4½
								1	18 6	5 3	5 6	4½
Water Street	1	Double-acting crank	30¼	6	Do.	12½	47	2	24 0	8 0	8 6	6
					Single-acting..	12⅜	42					
Windsor	1	Cornish	50¼	9 0	Bucket and plunger lifts	16⅛	105	4	33 0	5 3	Diamtr.	35
Green Lane	1	Cornish	50	9 0	2 plunger lifts	17	105	3	28 0	6 0	Diamtr.	35

* These pumps are here given as double-acting, but they were bucket pumps with close tops.—(See illustration.)

† Soho and Water Street were close top bucket pumps also, though described as double acting.

TABLE No. 2.

SHOWING THE QUANTITIES OF WATER IN THE WELLS ON MONDAY AND SATURDAY, WITH SPEED OF ENGINES, &c., FOR THE WEEK ENDING 10TH MARCH, 1849.

Station.	Water in Wells.		Average No.		Quantity of Water delivered per day in gallons.	Quantity raised by each Stroke.	Total quantity represented by the capacity of the pump.	Capacity of the pump per Stroke.
	Monday Morning.	Saturday Evening.	Hours per Day.	Strokes per Min.				
	Ft. In.	Ft. In.	Hrs Min.					
Bootle	9 9	0 0	24 0	11¾	1,093,950	See Note	to Bootle in	Table.
B. Bush..............	24 9	16 7	11 49	17¼	338,250	27·5	387,450	31·5
Soho	21 3	13 6	11 5	16½	360,250	33·0	383,715	35·1
Hotham Street ...	12 8	7 6	13 50	25¼	278,822	13·27	357,212	17·0
Water Street	12 9	5 11	11 35	17¾	398,275	36·7	420,401	38·75
Windsor	17 4	13 10	21 50	7½	728,075	75·	750,402	77·3
Green Lane	68 0	60 6	22 0	9¼	1,023,347	83·85	1,049,587	86·0

TABLE No. 3.

QUANTITY OF WATER RAISED, AND COAL CONSUMED, IN THE WEEK ENDING 10TH MARCH, 1849, AND AVERAGE QUANTITY RAISED FOR EACH 1 CWT. OF COAL CONSUMED.

Station.	Weekly consumption of Coal.	Weekly quantity of Water Pumped.	Quantity of Water delivered per Cwt. of Coal consumed.
	Cwts.	Gals.	Gals.
Bootle	781	6,563,700	8,404
Everton	165	1,959,820	11,877
B. Bush	231	2,029,500	8,785
Soho	220	2,161,500	9,825
Hotham Street ...	317	1,672,932	5,277
Water Street ...	495	2,389,651	4,827
Windsor	360	4,368,450	12,134
Green Lane ...	297	6,140,081	20,673

The next is a similar table from Mr. Hall's paper on the Settlingstones Engine, and is inserted for comparison :—

TABLE No. 3 A.

Station.	Duration of Experiment.	Strokes per Minute.	Gallons per Minute.	Coal.	Gallons per Cwt. of Coal.
	Hours.			Cwts.	
Hebburn...............	12	7·03	829	116	5145·5
Settlingstones	120	3·05	301	114	19,010·5
Do.	32	2·94	291	26	21,489·0

In a report made by Mr. Robert Stephenson to the Liverpool Corporation in 1850, showing the actual quantities of water delivered under various pressures and circumstances, is the following table of experiments made to verify the deliveries in order to test the yield of the wells :—

TABLE No. 4.—YIELD OF ONE STROKE OF PUMP.

Station.	Date of Experiment.	Yield of No. 1 Pump (outside).	Yield of No. 2 Pump (inside).	Yield of both Pumps.	Remarks.
	1850.				
Bootle ..	Jan. 1	32·89	..	..	Engine working 20 strokes, into Kirkdale reservoir.
	2	..	32·53	65 11	Do. 20 do. do.
	3	32·53	..	..	Do. 16 do. do.
	4	..	32·13	64·66	Do. 16 do. do.
B. Bush ..	31	..	..	20·86	Do. into Kirkdale reservoir.
	Feb. 3	..	..	20·53	Do. do.
Soho ..	Jan. 21	..	..	33·95	Do. 15 strokes at 37 lbs. pressure above main.
				33·15	Do. 12 „ 70 do.
	24	14·96	19·16	34·12	Do. 19 „ 40 do.
Hotham St.	Mar. 6	..	..	16·00	Measured over notch 18 inches wide. Water 5·6 above blast holes.
	14	..	..	14·26	Mean of the two experiments, 14·31. Water, 2·4 do.
	15	..	..	14·36	
Water St...	Jan. 5	17·37	..	..	Average of three experiments under 6 lbs. pressure above main at 17½ strokes per minute.
			19·66	..	Average of three experiments ; 31½ lbs. pressure ; 19 strokes.
			19·62	..	Engine at 17 strokes at 45 lbs. pressure.
			19·94	..	Do. 20½ do. 6 do.
				37·91	Do. 17½ do. } 6 do. No. 1 Pump. / 31½ do. 2 do.
	18	16·6	..	..	Pumping under 6 lbs. pressure.
		17·22	..	..	Do.
			19 99	..	Do.
				37·38	Mean of the foregoing experiments.
Windsor ..	12	..	..	76·73	Under 8 lbs. pressure. } Length of stroke, 8·75 feet.
				76·30	Do. 35 do.
	16	..	..	77·17	Do. 8 do.
				76·39	Do. 35 do.
Green Lane	Feb. 27	..	..	83·42	Engine making 9 strokes per minute.
				83·46	Experiment by measuring the flow of water over a weir—all others in tanks.

The manner in which the experiments were conducted is alluded to in the table, but a more detailed account will be acceptable to prevent mistakes.

One set of experiments was made by pumping for a number of hours into a circular reservoir of known diameter, carefully measuring the water, and ascertaining the number of strokes made by the engine.

Another set was taken by pumping into a large rectangular vessel divided across the middle into two tanks; each of which was provided with a large flap valve for discharging the water. On the top was a long box with a shuttle at either end, and into this box the water was pumped. About six inches of water were left in each tank; pumping began into No. 1 tank, and was kept up till it was nearly full when the shuttle was put down, and that into No. 2 tank was opened; the water in No. 1 was allowed to come to rest, the height noted, and then the valve was raised, and the water run off to nearly 6 inches of the bottom, when the gauge was taken, and the action reversed by closing No. 2 shuttle and opening No. 1, No. 2 being then gauged and run off, and so on alternately for a certain time when the number of strokes was taken, and so many feet of water, of say 15 feet × 12 feet, had been pumped and run off. Intermediate observations were made at stated intervals, of water and strokes, to verify the results.

A third method was applied to the Cornish engine, at Windsor, to ascertain, by a self-registering apparatus, the exact length of stroke made, or more correctly the total number of feet of plunger travelled, and to observe this apparatus at the same time as the ordinary engine counter. The following description will explain it. Upon the main gudgeon of the beam was fixed an arm of a length apportioned to the length of the half-beam, and a small connecting rod, fitted with ratches, was led to a ratchet wheel fitted with palls, both ratches and palls being so adjusted as to cover a tooth with the smallest possible loss. This ratchet wheel was keyed upon the first spindle with a pinion of 10 teeth gearing into a wheel with 100 teeth upon the second spindle, the gearing being continued through the train of spindles forming a register of tens as in an ordinary counter. The ratchet wheel was of such a size as to show 100 feet travelled by the plunger, and so the register could be read at any time with the counter, and the average length of stroke ascertained.

The fourth plan was by means of a notch and weir, and the result came very near to that taken by the cisterns or tanks.

It will be seen that great care was taken to ascertain the actual delivery of the pumps, because they were to be employed to measure the supply of water from the wells; hence, great accuracy was necessary to determine the point which was to form the basis of Mr. Stephenson's report.

As a comparison has been made between the crank and direct-acting engines, and as both examples are found in the tables appended, a description of the several engines employed is given, taken from Messrs. Simpson's and Newland's Report, and before alterations were made in the pumping arrrangements; for instance, at the B. Bush Station the pump was afterwards altered from a bucket to a plunger set, and a similar alteration was made at Soho and Water Street.

The result of one week's working is given in each instance.

Bootle Station.—There were three double-acting low pressure engines with cranks and fly wheels, each separate from the other, and each working a single-acting pump. Only two engines were worked at the same time, the other being kept in reserve. There were five boilers, but three were sufficient for two engines. There was an air-vessel outside the engine-house. Total lift, 170 feet.

TABLE No. 5.

Station.	Day of Week.	Hours Worked.	Height of Water in Well.		Number of Strokes.		Quantity of Water delivered.	
			Morning.	Evening.	No. 2 Engine.	No. 3 Engine.	Engineer's Return.	Calculated from capacity of Pump.
		H.	Ft. In.	Ft. In.			Galls.	
Bootle ...	Sunday ...	12	...	9 9	9,310	8,180	569,260	
	Monday ...	24	5 11	3 9½	18,710	15,860	1,120,860	
	Tuesday ...	24	2 11½	2 1	18,850	15,510	1,110,500	
	Wednesday	24	1 11½	1 7½	18,020	15,710	1,096,920	
	Thursday ...	24	1 6	1 1	18,220	15,090	1,077,320	
	Friday ...	24	0 9	0 6	17,620	15,400	1,074,120	
	Saturday ...	12	Below	gauge.	8,720	7,200	514,720	
Week's Work ...	...	144	...	...	109,450	92,950	6,563,700	8,017,845
Daily Average	...	24	...	...	18,242	15,492	1,093,950	1,336,307

	No. 1.	No. 2.	No. 3.
Capacity of pump	34·7	34·7	45·4 galls.
Engineer's adopted number ...	26·0	26·0	40·0 ,,

Average number of strokes per minute, 11¾.

Depth of well from surface about 40 feet.

Memorandum for Bootle Station.—The bottom of the lodgment was about the level of high water, spring tides, in the Mersey, and the water rose to about 22 feet depth. There were 16 boreholes sunk into the red sandstone, and the yield was 1,033,984 gallons per 24 hours. Fifteen of those boreholes were plugged up, and the yield then was 921,192 gallons, showing the value of the others to be only 112,792 gallons.

The cost of pumping 1 million gallons was, in 1849, £4 7s. 8d., and in 1854, £3 2s. 11½d., or for one million gallons raised 100 feet in 1849, £2 11s. 7d., and in 1854, £1 17s. 0d.

The average yield at the end of 1849 was found to be 850,691 gallons, and in 1854, 881,008 gallons; the total quantity pumped being less than in 1849, or only 321,567,770 gallons.

Everton Station.—This was a supplementary lift for high service, at the north end of the town, and there was a double-acting high pressure engine with crank and fly wheel working a double-acting pump, which delivered over a stand pipe.

TABLE No. 6.

Station.	Day o the Week.	Hours Worked.	Height of Water in Well.		Number of Strokes.	Quantity of Water delivered.	
			Morn.	Even.		Engineer's Return.	Capacity of Pump.
		H. M.	Ft. In.	Ft. In.		Galls.	Galls.
Everton...	Sunday.........	...			...	...	
	Monday	11 0			11,840	367,040	
	Tuesday	10 0			9,810	304,110	
	Wednesday ...	11 0			11,640	360,840	
	Thursday	9 0			8,800	272,800	
	Friday	11 0			11,540	357,740	
	Saturday	10 0			9,590	297,290	
Week's Work		62 0			63,220	1,959,820	2,092,582
Daily Average................		10 20			10,537	326,637	348,763

Capacity of pump, 33·1 gallons per stroke.
Engineer's adopted number of gallons per stroke, 31·0.
Average number of strokes per minute, 17.

Bevington Bush Station.—There was one single-acting low pressure engine with a single-acting bucket pump from the opposite end of the beam. The steam acted upon the top of the piston, only raising the pump rods and water, the return stroke being made by the weight of the rods. During the last quarter of the year 1849, the pump was altered, and a plunger substituted for the bucket, the weight of the rods aided by a weight on the beam forcing the water. The capacity of the pump, both before and after the alterations, was noted, and is given in the duty of the engine. There was a stand-pipe over which the water was delivered, giving a total lift of 228 feet from the bottom of the well. Well, 150 feet.

NOTE.—This engine was stopped at 12 noon, on 1st November, and was started at 7 a.m., on the 22nd. The depth of water, when the engine stopped, was 12 feet 10 inches, and 44·10 when it was put to work again.

TABLE No. 7.

Station.	Day of the Week.	Hours Worked.	Height of Water in Well.		Number of Strokes.	Quantity of Water delivered.	
			Morn.	Even.		Engineer's Return.	Capacity of Pump.
		H. M.	Ft. In.	Ft. In.		Galls.	
B. Bush...	Sunday ...						
	Monday ...	12 30	24 9	19 8	12,320	338,800	
	Tuesday ...	11 0	22 10	19 6	11,270	309,925	
	Wednesday ...	12 0	22 9	18 1	12,770	351,175	
	Thursday ...	12 10	21 9	17 10	12,800	352,000	
	Friday ...	12 0	21 6	16 7	12,730	350,075	
	Saturday ...	11 15	20 4	16 7	11,910	327,525	
Week's Work		70 55	...	...	73,800	2,029,500	2,324,700
Daily Average		11 49	...	...	12,300	338,250	387,450

Capacity of pump, 31·5 gallons per stroke.
Engineer's adopted number of gallons per stroke, 27·5.
Average number of strokes per minute, 17¼.
Depth of well from surface, 123 feet.
NOTE.—By actual measurement, this was 149·6 below engine room floor.

MEMORANDUM FOR BEVINGTON BUSH STATION.—The bottom of this well was 65 feet below the high water level of the Mersey in spring tides, and the yield at the end of 1849 was 180,875 gallons, while in 1854 it was 252,737 gallons per 24 hours.

The cost of raising 1 million gallons was, in 1849, £7 10s. 1d. including repairs, and in 1854, £5 10s. 11½d., or for 1 million gallons 100 feet high, £3 5s. 9d. and £2 8s. 8d. respectively, though the quantity pumped in 1854 was only 92,250,018 gallons.

SOHO STATION.—This engine was low pressure, double-acting, with crank and fly-wheel. There were two pumps, the one double-acting, worked from the beam, the other single-acting, worked from a crank on the outer end of the fly-wheel shaft, both delivering over a stand-pipe.

In the table of the capacity of these pumps, No. 1, there appears to be an error, but it is given as stated in the report. The lift was 247 feet above the bottom of the well. Well, 140 feet.

TABLE No. 8.

Station.	Day of Week.	Hours Worked.		Height of Water in Well.				Number of Strokes.	Quantity of Water delivered.	
				Morn.		Even.			Engineer's Return.	Capacity of Pump.
		H.	M.	Ft.	In.	Ft.	In.		Galls.	Galls.
Soho ...	Sunday.........	...		...		...		...	...	
	Monday	11	0	21	3	15	9	11,168	368,544	
	Tuesday	10	30	19	4½	15	7	9,482	312,906	
	Wednesday ...	11	0	19	2½	14	6	11,577	382,041	
	Thursday	12	0	18	6	15	1½	9,988	329,604	
	Friday	11	0	18	6½	13	11½	11,986	395,538	
	Saturday	11	0	17	10	13	6	11,299	372,867	
Week's Work		66	30	...		...		65,500	2,161,500	2,229,050
Daily Average..............		11	5	...		...		10,917	360,250	383,715

Capacity of pump, 35·1 galls. per stroke.

Engineer's adopted number of galls. per stroke, 33·0.

Average number of strokes per minute, 16½.

Depth of well from surface about 123 feet.

NOTE.—This was measured 146 feet to bottom, which was fully 2 feet below the suction pipe.

MEMORANDUM FOR SOHO STATION.—This well was 39 feet below the high water level of spring tides, and the average yield per 24 hours was, in 1849, 497,869 gallons, and in 1854, 509,732 gallons.

The cost per million gallons was £4 18s. 9d. in 1849, and £4 6s. 3d. in 1854, or per 100 feet raised £2 0s. 0d., and £1 14s. 11d., at which 186,052,194 gallons were pumped.

HOTHAM STREET.—There was a double-acting beam engine, with crank and fly-wheel working a double-acting pump from the beam, all of which were old and in a defective condition. There was an air-vessel in the well close to the pump, and a stand-pipe on the top of the well, close to the engine-house. The pump was placed high in the well, and was working under difficulties of position and repair—with a total lift of 205 feet. Well, 110 feet.

TABLE No. 9.

Station.	Day of the Week.	Hours Worked.		Height of Water in Well.				Number of Strokes.	Quantity of Water delivered.	
				Morn.		Even.			Engineer's Return.	Capacity of Pump.
		H.	M.	Ft.	In.	Ft.	In.		Galls.	Galls.
Hotham Street.	Sunday	...		...		...		...	...	
	Monday	20	0	12	8	6	1	30,445	404,005	
	Tuesday	14	0	8	5	5	7	20,946	277,873	
	Wednesday ...	14	0	9	10	6	0	21,559	286,087	
	Thursday	14	0	10	0	6	3	20,773	275,657	
	Friday	6	0	10	0	8	0	10,498	139,308	
	Saturday	15	0	11	0	7	6	21,854	290,002	
Week's Work		83	0	...		...		126,075	1,672,932	2,143,275
Daily Average...............		13	50	...		...		21,012	278,822	357,212

Capacity of pump, 17 galls. per stroke.
Engineer's adopted number of galls. per stroke, 13·27.
Average number of strokes per minute, 25¼.
Depth of well from surface, about 110 feet.

Memorandum for Hotham Street Station.—This well was 26 feet below high water mark, spring tides, and the average yield was 216,381 gallons in 1849, and 229,201 in 1854; the cost per million gallons being £7 9s. 4d. and £8 3s. 4d., or per 100 feet, £3 12s. 10d., and £3 19s. 8d. in 1854, when the quantity pumped was 83,658,450 gallons.

Water Street.—This station was called Park in the former paper, and was known by both names. There was a double-acting low pressure beam engine working two pumps, the one single-acting worked from the beam, the other single-acting worked from a crank at the outer end of the fly-wheel shaft. There was a stand-pipe connected with one of the pumps only. Total lift, 257 feet. Well, 157 feet.

TABLE No. 10.

Station.	Day of the Week.	Hours Worked.		Height of Water in Well.				Number of Strokes.	Quantity of Water Delivered.	
				Morn.		Even.			Engineer's Return.	Capacity of Pump.
		H.	M.	Ft.	In.	Ft.	In.		Galls.	Galls.
Water St.	Sunday.........	...		...		...		...		
	Monday	12	0	12	9	7	1	13,570	498,019	
	Tuesday	10	0	10	9	7	0	10,860	398,562	
	Wednesday*	10	0	11	1	9	0	11,220	238,974	
	Thursday* ...	12	30	12	2	8	8	13,700	329,990	
	Friday	13	0	11	9	6	9	12,600	462,420	
	Saturday	12	0	10	4	5	11	12,580	461,686	
Week's Work		69	30	...		...		74,530	2,389,651	2,522,406
Daily Average...............		11	35	...		...		12,422	398,275	420,401

* The single-acting pump was idle part of the Wednesday and Thursday.

Capacity of pump, 38·75 gallons per stroke.

Engineer's adopted number, 36·7 gallons per stroke.

Average number of strokes per minute, 17¾.

Depth of well from surface about 156 feet.

Memorandum for Water Street Station.—The bottom of this well was 52 feet below high water mark, spring tides, and the average yield per 24 hours was, in 1849, 419,264 gallons, and in 1854, 402,344 gallons.

The cost of pumping was £5 16s. 6d. and £4 4s. 6d., or for 100 feet lifted, £2 5s. 4d. and £1 12s. 10½d. for 1849 and 1854; the quantity of water pumped being 146,855,645 gallons.

Windsor.—A single acting high-pressure condensing engine worked a set of pumps in two lifts, the lower being a bucket, and the upper a plunger lift. There was also a jack pump to the cistern for the upper lift. An air vessel was provided for this pump. Total lift, 287 feet. Well, 212 feet.

TABLE No. 11.

Station.	Day of Week.	Hours Worked.		Height of Water in Well.				Number of Strokes.	Quantity of Water delivered.	
				Morn.		Even.			Engineer's Return.	Capacity of Pump.
		H.	M.	Ft.	In.	Ft.	In.		Galls.	Galls.
Windsor...	Sunday.........	...		...		...		...	...	
	Monday	17	0	17	4	14	4	6,396	704,700	
	Tuesday	17	0	16	10	14	3	8,972	692,900	
	Wednesday ...	25	30	16	9	15	10	10,478	785,850	
	Thursday	23	30	13	11	14	6	10,360	777,000	
	Friday	24	0	12	9	14	0	9,830	737,250	
	Saturday	24	0	12	3	13	10	9,210	690,750	
Week's Work		131	0	...		...		58,246	4,368,450	4,502,415
Daily Average		21	50	...		...		9,708	728,075	750,402

Capacity of pump, 77·3 galls. per stroke.

Engineer's adopted number, 75 galls. per stroke.

Average number of strokes per minute, 7½.

Depth of well from surface about 210 feet.

Memorandum for Windsor Station.—The bottom of this well was 37 feet below the high water mark, spring tides, and the average yield was, in 1849, 678,560 gallons, and in 1854, 1,020,493 gallons; the cost of pumping being £4 1s. 6d. and £2 12s. 0d. per million gallons, or for each 100 feet £1 8s 5d. and £0 18s. 1½d. in the years 1849 and 1854, in which latter year the quantity raised was 372,480,000 gallons.

Green Lane.—There was a single acting high-pressure condensing engine working one set of pumps in two plunger lifts (equal to 83·85 gallons per stroke), and there was also one drawing lift (97 gallons per stroke) for reducing the water to repair the lower set of bucket pumps. This engine delivered over a standpipe into a reservoir, and worked under regular conditions; it had not been long in use, and the valves were worked by segments and cataract. Total lift, 270 feet. Well, 196 feet.

TABLE No. 12.

Station.	Day of the Week.	Hours Worked.		Height of Water in Well.				Number of Strokes.	Quantity of Water delivered.	
				Morn.		Even.			Engineer's Return.	Capacity of Pump.
		H.	M.	Ft.	In.	Ft.	In.		Galls.	Galls.
Green Lane.	Sunday.........	...		...		...		...	...	
	Monday	24	0	68	0	62	6	13,244	1,110,509	
	Tuesday	24	0	62	6	62	0	13,318	1,116,714	
	Wednesday ...	24	0	61	6	61	0	13,394	1,123,086	
	Thursday	24	0	61	0	61	0	13,368	1,120,906	
	Friday	24	0	61	6	61	0	13,284	1,113,863	
	Saturday	12	0	61	0	60	6	6,619	555,003	
Week's Work		132	0	...		...		73,227	6,140,081	6,297,522
Daily Average...............		22	0	...		...		12,204	1,023,347	1,049,587

Capacity of pump, 86 gallons per stroke.
Engineer's adopted number, 83·85 gallons per stroke.
Average number of strokes per minute, 9¼.
Depth of well from surface, about 185 feet.

Memorandum for Green Lane Station.—The bottom of the well was 63 feet below high water mark, spring tides, and the average yield per 24 hours was 991,118 gallons in 1849, increased to 2,413,068 gallons in 1854, the cost of pumping being in 1849, £2 10s. 1d., and in 1854, £2 2s. 5¾d. per million gallons, or per million gallons raised 100 feet, £0 18s. 6d. and £0 15s. 9d. respectively; the quantity raised in 1854 being 880,769,922 gallons.

The cost of the Green Lane Station is given by Mr. Duncan, the late engineer to the water-works, as under:—

Cost of the well	£6,600
"John Holmes" engine, 50 inch cylinder	5,782
Engine and boiler house and tower	4,278
"George Holt" engine, 52 inch cylinder, including buildings, boilers, pumps, and fixing	6,500
	£23,160

While in some of the Liverpool wells there has been an increase of yield, it was found at Wolverhampton that there was much less water in the sandstone, one well producing only 168,000 gallons per day; but this may be partly accounted for by the fact that where it was sunk the ground was 450 feet above the level of the sea, and partly by the increased permeability of the one rock over the other.

Most of these engines and pumps were illustrated in the former paper.

The wells were not merely what are known as such in ordinary terms; wells were sunk, and from the bottom, tunnels or lodgments were formed of considerable extent, and in some cases bore-holes were driven to a great depth in the red sandstone to increase the supply; in the Soho well there was one about 300 feet deep. At Windsor, at the end of the year 1849, a bore-hole was being sunk, which was carried to a depth of 189 feet; on the 22nd of March, 1850, when the increase was found to be 241,000 gallons per 24 hours, the yield obtained, the depth, and the strata passed having been recorded regularly. The Bootle Station had not a well, but a sump was formed, into which the water was carried by pipes from lodgments 46 to 50 feet deep, cut out of the rock, and from which bore-holes were run, varying in depth to 600 feet; and an interesting set of experiments was here made to test the value of boring, some being plugged and others left open, to ascertain the porosity of the red sandstone, and so, on a small scale, to see whether a greater number of wells could give a proportionably greater supply of water.

The Tables No. 3 and 3A show the consumption of fuel and quantity of water raised during a given time; and the same is tabulated to show the quantity of water raised by 1 cwt. of fuel. In the examples given in Table No. 3, the quantity of fuel stated includes that used for raising steam, and even that taken for the enginemen's houses; while in Table 3A there are some experiments given which will most likely not include more than the net amount burnt under the boilers during the experiments.

There is another thing to be named; the lift of water is not given in the tables. It will be seen that in the supply of a town by means of either air-vessels or stand pipes, there must be pressures ever varying with the services, and no engine was under worse conditions on its high services than Windsor, where, at one particular service, the large pump was kept going slowly on a small main. The average lift may be taken as 240 feet, but is believed to be more than that.

The advantage of the Cornish engine consists partly in its power of being adapted to an increase of work, by allowing the steam to act on the piston for a greater length of the stroke; in being usually constructed with a long stroke; in the perfect way in which the number of strokes can be regulated and its velocity checked at any portion of its stroke.

Many of the American pumping engines are said to be high pressure non-condensing, and the duty is said to be for each cwt. of coal:—

			Feet pounds.
Pittsburgh Upper Water Works, 1852		... ...	19,941,600
Do. Lower	do.	... ...	19,112,576
Alleghany City	do.	... ...	19,226,700
Detroit	do.	... ...	17,397,856

It is also recorded that American engineers are in the habit of allowing one-third for leakage in the pumps, so as to ensure the delivery of the quantity required.

The next table is one which gives an answer to many opinions expressed, and, having the weight of facts and figures given by Mr. Robert Stephenson, will be received with its full value. It gives the quantity of water distributed by each station, and the cost of the work and repairs during the year 1849, and a column is given in which the cost of the Green Lane pumping engine on the Cornish principle is worked out on the quantities raised by the other engines, and the loss by comparison is shown, giving a decided opinion upon the relative value of crank and direct pumping engines.

TABLE No. 12A.

COST OF RAISING WATER AT THE SEVERAL STATIONS, AND COMPARISON WITH GREEN LANE FOR THE YEAR ENDING 29TH DECEMBER, 1849.

Station.	Total Water raised.	Water used for condensing.	Nett Water raised for distribution.	Total cost of raising Water, per annum.	Cost per annum of raising one million gallons.	Water raised per day.	Cost of raising water at each Station at the same rate per million gallons as at Green Lane.	Loss by raising water at existing Stations.
	Galls.	Galls.	Galls.	£ s. d.	£ s. d.	Galls.	£ s. d.	£ s. d.
Bootle ..	329,486,250		329,486,250	1445 3 3	4 7 8	902,702	823 14 4	621 8 11
B. Bush ..	95,433,850		95,433,850	716 3 5	7 10 1	261,463	238 11 8	477 11 9
Soho.. ..	168,812,589		168,812,589	833 17 1	4 18 9	462,500	411 0 8	422 16 5
Hotham St.	80,783,436		80,783,436	603 4 8	7 9 4	221,334	201 19 2	401 5 6
Water Street	150,038,675		150,038,675	874 7 10	5 16 6	411,065	375 2 0	499 5 10
Windsor ..	252,922,650	20,233,812	232,688,838	949 0 3	4 1 6	637,504	581 14 5	367 5 10
Green Lane	367,378,629		367,378,629	920 2 7	2 10 1	1,006,517	920 2 7	Nil.

NOTE.—It is believed that by an alteration of the boilers at Windsor, that station may be worked nearly as economically as Green Lane.

To supplement the table just given, the following extracts from the official records of the Corporation will supply full information as to the amount of stores supplied, and will enable the members to estimate for themselves the value of the work done at present prices.

TABLE No. 13.

ABSTRACT OF STORES AND DUTY FOR QUARTER ENDING 31st MARCH, 1849.

Stations.	Coal. T. C.	Slack. T. C.	Tallow. lbs.	Engine Oil. lbs.	Lamp Oil. lbs.	Waste. lbs.	Hemp and Rope. lbs.	Leather. lbs.	Hours Working. H. M.	Strokes.	Water Pumped. Galls.	
Bootle	359 5	118 18¾	351	67½	179¾	69½	39¾	...	No. 1 1371 0 ,, 2 571 30 ,, 3 1826 0	983,360 440,030 1,127,440	86,038,980	Mean Pressure on Main 31·25 Temperature of Cistern 64·9, Hot Well 99·8
Everton	107 9	...	48	23¼	2	14¼	19	...	798 0	796,980	24,706,380	
B. Bush	136 13½	6 12	160	12	...	18	...	...	937 50	1,039,370	25,568,080	Do. 62·0 Do. 102·0
Soho	159 10¾	13 15¼	149	32¾	...	37	32¼	30	902 35	895,611	29,555,162	Do. 59·3 Do. 99·5
Hotham Street ...	202 14¾	...	128	34½	2½	28	59	...	1111 30	1,614,594	21,430,325	Do. 71·12 Do. 91·2
Water Street	314 11	9 14	261	41½	...	33	82	19¼	894 30	960,599	34,908,373	Do. 90·0 Do. 110·0
Windsor	262 15¼	...	356	67	13¼	82	93¾	...	2026 0	859,948	64,496,100	Do. 54·6 Do. 100·15
Green Lane	137 11½	65 0	280	88	...	56	91½	...	1795 45	1,002,737	84,079,497	Do. 53·8 Do. 96·6
Total	1700 10¾	214 0	1733	366½	197½	337¾	417¼	49¼	12,234 40	9,720,669	370,782,897	

TABLE No. 14.

ABSTRACT OF STORES AND DUTY FOR QUARTER ENDING 30TH JUNE, 1849.

Station.	Coal. T. C.	Slack. T. C.	Tallow. Lbs.	Engine Oil. Lbs.	Lamp Oil. Lbs.	Waste. Lbs.	Hemp and Rope. Lbs.	Leather. Lbs.	Hours Working. H. M.	Strokes.	Water Pumped. Galls.	
Bootle	346 7¾	117 16	333	70	67¼	51½	60	...	No. 1 1168 30 ,, 2 570 30 ,, 3 1799 30	877,720 480,590 1,140,880	83,656,650	Pressure on Main, 31·23 Temperature of Cistern 74·7, Hot Well 105·1
Everton	110 8¼	...	73	22½	3	13½	12	...	852 0	825,850	25,633,030	
B. Bush	136 1	7 8½	154	12	...	19	...	...	984 35	1,017,500	26,455,000	Do. 62 Do. 102
Soho	252 8¼	4 13	283	44¼	...	48¾	43½	42	1550 55	1,508,938	46,663,674	Do. 61·3 Do. 101·7
Hotham Street... ...	164 8¼	...	116	22	3¼	14	47½	...	1032 0	1,505,277	19,975,026	Do. 74·3 Do. 94·7
Water Street	286 10¼	12 6	233	40	...	38	35	66	930 30	1,011,760	36,652,342	Do. 60·0 Do. 110·0
Windsor...	256 15¾	...	410½	54	10½	71	47½	...	1831 30	844,894	63,367,050	Do. 54·05 Do. 100·0
Green Lane	149 11¼	77 0	222	113	...	60½	34	...	1991 0	1,139,608	95,556,130	Do. 69·18 Do. 106·78
Total	1702 10¾	219 3½	1824½	377¾	84	316¼	279½	108	12,711 0	10,353,017	397,958,902	

TABLE No. 15.

ABSTRACT OF STORES AND DUTY FOR QUARTER ENDING 29TH SEPTEMBER, 1849.

Station.	Coal. T. C.	Slack. T. C.	Tallow. Lbs.	Engine Oil. Lbs.	Lamp Oil. Lbs.	Waste. Lbs.	Hemp and Rope. Lbs.	Leather. Lbs.	Hours Working. H. M.	Strokes.	Water Pumped. Galls.	
Bootle	327 16¼	116 13	332¼	70½	62½	60	59½	...	No. 1 1094 0 ,, 2 783 0 ,, 3 1330 0	909,740 636,610 963,340	82,377,660	Mean Pressure on Main 31·76. Temperature of Cistern 81·15, Hot Well 109·5
Everton	119 2¼	...	61	24	2	15	21	...	913 0	937,110	29,019,410	
B. Bush	145 16	6 10	178	12	...	20	...	...	1073 0	1,036,580	26,951,080	Do. 62 Do. 102
Soho	263 18	4 10	299½	75	...	60¾	48½	25	1587 0	1,439,057	47,287,663	Do. 62·17 Do. 102·5
Hotham Street ...	151 2½	...	160	20½	3¼	15	42	...	1092 40	1,476,572	19,687,361	Do. 74·9 Do. 95·04
Water Street	298 8½	7 5	244	46	...	41½	73	35	1098 0	1,162,990	40,314,860	Do. 60·0 Do. 110
Windsor	214 1	67 9	364	60¾	6½	76½	65	...	1593 55	840,140	63,310,500	Do. 54 Do. 100
Green Lane	163 13¾	82 14¼	352	114	...	78½	29	...	2081 15	1,155,804	96,914,165	Do. 76·24 Do. 114·9
Total	1683 18½	285 1¼	1990¾	422¾	74¼	367¼	338	60	12,645 50	10,557,943	405,862,699	

TABLE No. 16.

ABSTRACT OF STORES AND DUTY FOR QUARTER ENDING 29th DECEMBER, 1849.

Station.	Coal. T. C.	Slack. T. C.	Tallow. lbs.	Engine Oil. lbs.	Lamp Oil. lbs.	Waste. lbs.	Hemp and Rope. lbs.	Leather. lbs.	Hours Working. H. M.	Strokes.	Water Pumped. Galls.	
Bootle	321 3¾	101 17½	245¾	75	145½	72	72½	...	No. 1 1660 30 ,, 2 1104 30 ,, 3 384 0	1,378,495 970,335 270,800	77,412,960	Mean Pressure on Main 31·52 Temperature of Cistern 72·4, Hot Well 100·8
Everton	82 16½	...	59	22	2	11¾	20	...	847 0	816,030	25,296,930	
B. Bush*	109 18¼	6 14	232	19	...	37	...	...	792 42	708,790	16,459,690	Do. 62·0 Do. 105·8
Soho	276 5¼	8 4¾	263½	64½	...	61½	46½	32¾	1602 50	1,374,380	45,306,090	Do. 61·8 Do. 103·4
Hotham Street ...	164 6	...	150	23	4	24	29	...	1128 0	1,483,856	19,690,734	Do. 75·8 Do. 97·36
Water Street	219 11¾	77 10¼	208	39½	...	38½	62	35	1019 30	1,064,280	38,153,100	Do. 60 Do. 110
Windsor	157 14	132 3	364	55	5¾	73½	39¾	...	1608 10	823,320	61,749,000	Do. 54 Do. 100
Green Lane	144 3¾	97 5¼	350	116	...	78	57	...	2130 15	1,083,228	90,828,835	Do. 63·67 Do. 107·36
Total	1475 19¼	423 14¾	1872¼	414	157¼	396¼	326¾	67¾	12,277 33	9,973,414	374,897,339	

* Bevington Bush engine off for alterations during three weeks in this quarter.

TABLE No. 17.

ABSTRACT OF STORES AND DUTY FOR THE YEAR ENDING 29TH DECEMBER, 1849.

Station.	Coal.		Slack.		Tallow.	Engine Oil.	Lamp Oil.	Waste.	Hemp and Rope.	Leather.	Hours Working.		Strokes.	Water Pumped.
	T.	C.	T.	C.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	H.	M.		Galls.
Bootle	1354	12¾	455	5¼	1262	283	455	253	231	...	13,663	0	10,179,240	329,486,250
Everton	419	16	......		241	91¾	9	54½	72	...	3,410	0	3,375,970	104,655,750
B. Bush	528	8¾	27	4½	724	55	...	94	...	...	3,788	13	3,802,240	95,433,850
Soho	952	2¼	31	3	995	216½	...	208	170¾	129¾	5,643	20	5,217,986	168,812,589
Hotham St.	682	11¼	......		554	100	13	81	177½	...	4,364	10	6,080,299	80,783,326
Water St.	1119	1½	106	15¼	946	167½	...	151	252	155¼	3,942	30	4,199,620	150,038,675
Windsor...	891	6	199	12	1494	236¾	36	303	246	...	7,059	35	3,368,302	252,922,650
Green Lane	595	0¼	321	19½	1204	431	...	273	211½	...	7,998	15	4,381,377	367,378,629

TABLE No. 18.

SUMMARY OF STORES AND DUTY FOR THE YEAR ENDING 29th DECEMBER, 1849.

Quarter Ending.	Coal. T. C.	Slack. T. C.	Tallow. lbs.	Engine Oil. lbs.	Lamp Oil. lbs.	Waste. lbs.	Hemp and Rope. lbs.	Leather. lbs.	Hours Working. H. M.	Strokes.	Water Pumped. Galls.
31st March	1700 10¾	214 0	1733	366½	197½	337¾	417¼	49¼	12,234 40	9,720,669	370,782,897
30th June	1702 10¾	219 3½	1824½	377¾	84	316¼	279½	108	12,711 0	10,353,017	397,958,902
29th September	1683 18½	285 1¼	1990¼	422¾	74¼	367¼	338	60	12,645 50	10,557,943	405,862,609
29th December	1475 19¼	423 14¾	1872¼	414	157¼	396¼	326¾	67¾	12,277 33	9,973,414	374,897,339
Total	6562 19¼	1141 19½	7420½	1581	513	1417½	1623¼	591½	49,869 3	40,605,043	1,549,501,837

Though the object of pumping in this instance was not to keep down the water as in mining operations, but to obtain a supply of water for the town, the question of the cost will not be affected by the object, and the writer may be allowed to insert the following tables, showing the yield of the several wells, and therefore the full quantity available to meet the requirements under the best conditions :—

TABLE No. 19.

YIELD OF WELLS.—BOOTLE STATION.

Date.	Level.		Yield in 24 Hours.
1849.	Ft.	In.	Gallons.
December 30	9	4	564,344
„ 31	6	6	837,134
1850.			
January 1	4	3	981,576
„ 1	3	7	969,184
„ 1	3	4	1,022,544
„ 1	2	5	1,096,371
„ 2	2	4	1,018,018
„ 2	2	4	1,078,092
„ 2	1	7	1,102,065
„ 3	2	0	979,944

	Ft.	In.
Mean height of water, week ending 22nd Dec... ...	3	9¾
Mean level of quarter	2	0½

TABLE No. 20.

YIELD OF WELLS.—B. BUSH STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
March 11	19	9	224,688
January 30	3	11	356,482
February 2	0	6	395,983

	Ft.	In.
Mean height of Water in month ending 11th March ...	13	6
Do. do. week „ 12th January...	12	11
Do. do. do. „ 19th do. ..	14	4
Do. do. do. „ 26th do. ...	5	11½
Do. do. do. „ 2nd February...	6	11½

TABLE No. 21.

YIELD OF WELLS.—SOHO STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
January 7	13	6	250,914
„ 14	13	6	329,508
„ 7	12	6	321,697
„ 14	12	6	340,735
„ 7	11	6	372,954
„ 14	11	6	406,149
„ 15	10	6	434,462
„ 15	9	6	453,988
„ 15	8	6	494,017
„ 15	7	6	527,212
„ 16	6	6	547,715
„ 16	5	6	575,052
„ 16	4	6	603,365
„ 16	3	6	603,852
„ 17	2	6	640,856
„ 17	1	6	659,016
„ 17	0	6	664,385

Experiments on and after the 14th give a greater yield, owing to a higher mean level of water.

	Ft.	In.		Ft.	In.
Mean level of water for week ending December 15th...	4	$3\frac{1}{2}$			
Do. do. „ 22nd...	5	$0\frac{1}{8}$			
Do. do. „ 29th...	6	$6\frac{3}{4}$			
Do. do. January 5th...	4	$4\frac{3}{4}$	Mean for 4 weeks...	5	$0\frac{1}{3}$
Do. do. „ 12th...	6	$8\frac{1}{8}$	„ „ ...	5	8

TABLE No. 22.

YIELD OF WELLS.—HOTHAM STREET STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
March 6	5	2	354,552
„ 14	2	4	447,048
„ 15	2	4	426,336

	Ft.	In.
Mean level of water for week ending 9th February ...	6	$8\frac{3}{4}$
Do. do. „ 16th do. ...	7	4
Do. do. „ 23rd do. ...	8	$7\frac{1}{4}$
Do. do. „ 2nd March ...	7	1
Do. do. month „ do. ...	7	$5\frac{1}{4}$

TABLE No. 23.

YIELD OF WELLS.—WATER STREET STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
January 21	10	0	187,385
„ ... 21	9	0	286,113
„ 21	8	0	327,672
„ 22	7	0	389,476
„ 7	7	0	391,075
„ 22	6	0	511,488
„ 22	5	0	516,283
„ 7	5	0	525,338
„ 8	4	0	512,020
„ 22	4	0	564,235
„ 5 & 6 ...	3	9½	574,358
„ 6	3	3	596,203
„ 12	3	0	592,473
„ 23	3	0	612,187
„ 12	2	0	630,835
„ 23	2	0	652,680
„ 23	1	6	683,582
„ 24	1	0	715,550

	Ft.	In.		Ft.	In.
Mean level of water for week ending 15th December	5	2½			
Do. do. 22nd do. ...	5	4¾			
Do. do. 29th do. ...	6	5½			
Do. do. 5th January ...	5	3¼	Mean for 4 weeks ...	5	7
Do. do. 12th do. ...	4	8⅛			
Do. do. 19th do. ...	5	5½	Mean do. ...	5	5½

Difference of mean levels, 1½ inches on the month in favour of the first, and on the week 2¼ inches in favour of the second experiments.

TABLE No. 24.

YIELD OF WELLS.—WINDSOR STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
January 13	6	$2\frac{5}{8}$	634,752
„ 14	5	$0\frac{3}{4}$	687,223
„ 14	4	$2\frac{1}{2}$	665,133
„ 15	3	$4\frac{1}{2}$	676,786
„ 16	1	10	716,830
„ 17	1	2	694,504
„ 17	0	$4\frac{1}{4}$	660,864

	Ft.	In.
Mean level of water for week ending 22nd December ...	4	$7\frac{1}{8}$
Do. do. 29th do. ...	4	7
Do. do. 5th January ...	6	$5\frac{1}{2}$
Do. do. 12th do. ...	4	$1\frac{1}{2}$
Do. do. month ending 12th do. ...	4	$11\frac{1}{4}$

TABLE No. 25.

YIELD OF WELLS.—GREEN LANE STATION.

Date.	Level.		Yield in 24 Hours.
1850.	Ft.	In.	Gallons.
February 27	38	$10\frac{3}{4}$	1,079,154
„ 28	28	7	1,163,640
March 1	19	$2\frac{1}{2}$	1,307,808
„ 2	12	$1\frac{1}{4}$	1,257,912
„ 3	9	0	1,257,192
„ 4	7	$4\frac{3}{4}$	1,248,816
„ 7	53	4	933,264

	Ft.	In.		Ft.	In.
Mean level of Water for week ending 2nd February ...	84	$5\frac{1}{4}$			
Do. do. 9th do. ...	43	$5\frac{1}{2}$			
Do. do. 16th do. ...	42	3			
Do. do. 23rd do. ...	31	5	Mean of month...	50	$4\frac{1}{2}$
Mean average during previous quarter				66	1

Above results somewhat under the yield in previous quarter.

TABLE No. 26.

YIELD OF WELLS AT PRACTICAL LEVEL.

Station.	Date.	Level.		Yield in 24 Hours.	Experiments.			Yield in 24 Hours.
					Date.	Level.		
	Quarter ending, 1849.	Average for Quar. Ft.	In.		1850.	Ft.	In.	
Bootle ...	December 29	2	0½	850,691	Jan. 3	2	0	979,944
B. Bush ...	Ditto	20	3	180,875	Mar. 11	19	9	224,688
Soho ...	Ditto	6	1⅓	497,869	Jan. 16	6	6	547,715
Hotham Street	Ditto	6	10¾	216,381	Mar.	5	2	354,552
Water Street	Ditto	6	2½	419,264	Jan. 22	6	0	511,488
Windsor ...	Ditto	4	6	678,560	Jan. 14	4	2½	665,133
Green Lane ...	Ditto	54	1	991,118	Mar. 7	53	4	933,264

From the above tables it will be seen that the greatest care was taken to arrive at correct conclusions, and it may be explained that at the different levels the pumping was maintained for three, four, or six hours, and experiments were made both in pumping down from foot to foot of the water, and in the rising of the water in the well, and the results obtained are given in the tables. The experiments extended over nearly three months, and are compared with the actual working as recorded in the official documents kept by the Corporation officials.

An interesting circumstance was noted during the experiments, at first chiefly at night, and it is referred to by Mr. Stephenson in his report. It was found in working at one level, and after it had been maintained for some time by the engine going a regular speed, that the water began to gain upon it, and this was at once set down as being caused by the sympathy or connection between the waterworks wells and those of private firms which were left to rise at night. Upon continuing the observations the same was found to occur at nearly regular intervals, but at varying times, and that at one time the engine had to be eased, at another quickened, to keep the water at the desired point, and by noting these facts and the times when they occurred, they were found to come very near that of two hours after high and low water. Whether this was caused by the rock being charged from the sea filtration, or other reason, is worth the careful consideration of members having pumping engines near to the sea, or to tidal rivers.

The permeability of the sandstone rock has been alluded to in the memorandum to the Bootle Station and in another place, and observations made at Bootle upon the group of bore-holes there, were supposed to assimilate to the result of a group of wells. The actual results are not given, as, though very interesting, they do not come within the subject of this paper.

The object of the stand-pipe is to give a regular head under which the engine shall be worked and to prevent the jar or blow of pumping direct into the mains. The air-vessel is to provide a cushion or spring, against which the plunger shall work, and it should be placed close to the pump-barrel, and be connected to it by means of a pipe fully as large as the working barrel, so that the whole contents of the pump may be forced into it freely and be discharged in a continuous stream by the recoil of the air-spring. In discharging water into an air-vessel the water may take up some of the air and so gradually exhaust the vessel, or the air may escape through the interstices of the metal itself, but the size may have something to do with this result. Air-vessels have been placed upon suction-pipes, but what may have been the intention when they were so placed it is difficult to see, as the air must have been exhausted before the pump could draw. Perhaps it may be allowed to class this as another fallacy with regard to pumping.

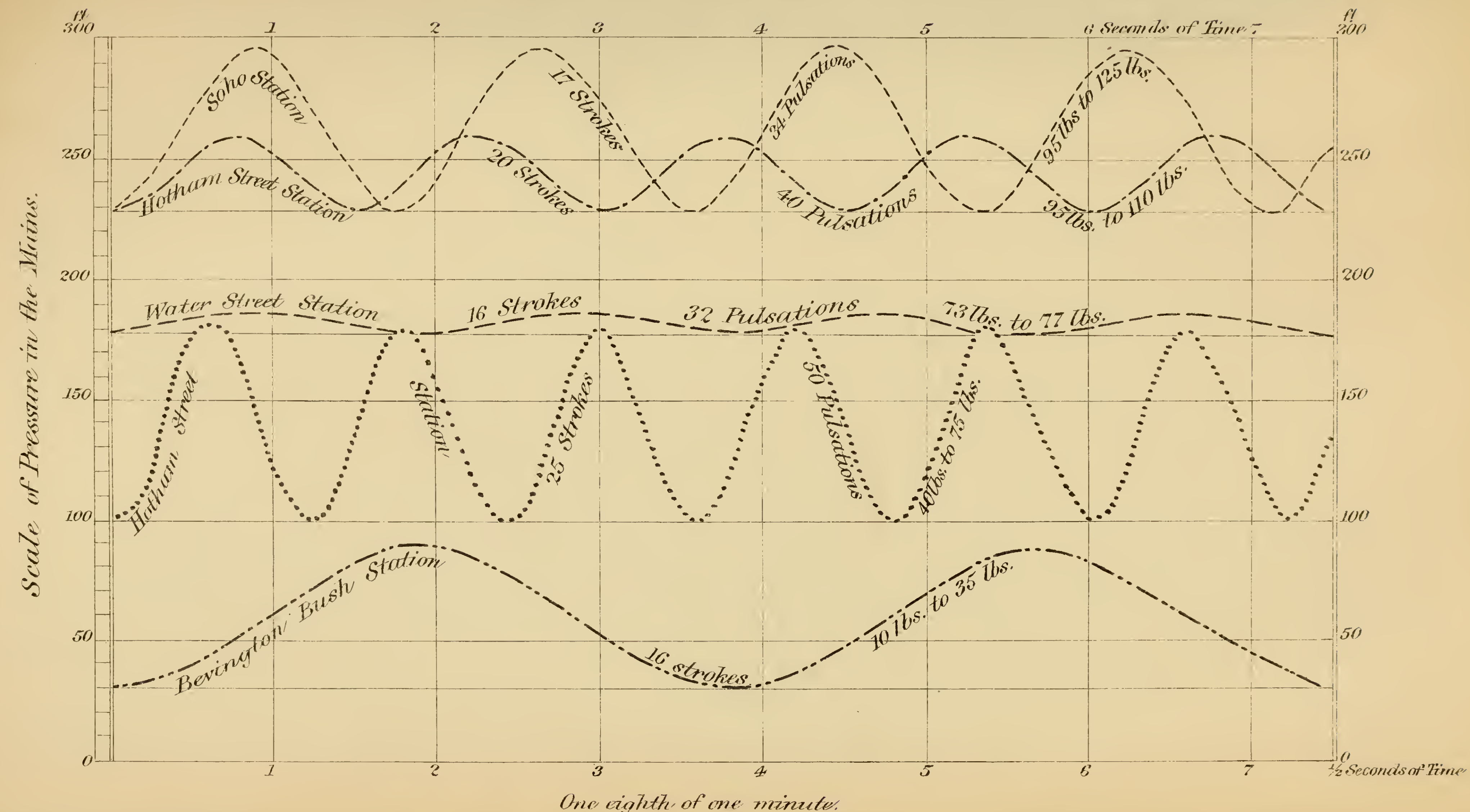
The delivery of water from a pump must necessarily be intermittent whether the shock be taken by air-vessel or stand-pipe, and the diagrams given by Mr. Bainbridge and Mr. Hall may be partly confirmed by one now given, Plate XXX., and which was briefly referred to by the writer at the last meeting. The pulsations of the pumps must be more or less communicated to the mains or arteries for distributing what the engine, the heart of the system, has forced; and the diagram, Plate XXX., shows in one form what is tabulated and given below:—

TABLE No. 27.—PULSATIONS IN THE MAINS.

Name of Station.	Strokes per Minute.	Vibrations per Minute.	Pressure in Mains per Sq. In. Pounds.	Pressure in Mains per Sq. In. Feet.
Bevington Bush ...	16	16	10 to 35	33 to 90
Soho	17	34	95 to 125	228 to 296
Hotham Street ...	25	50	40 to 75	101 to 181
Ditto ...	20	40	95 to 110	228 to 262
Water Street ...	16	32	73 to 77	177 to 186

B. Bush.—When the engine was delivering on high service at 16 strokes per minute, the index hand of the pressure-gauge vibrated

DIAGRAM SHOWING THE PULSATIONS OR OSCILLATIONS OF PRESSURE IN THE MAINS.

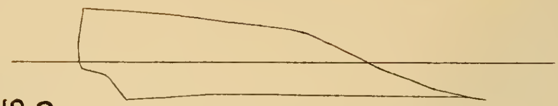


B. BUSH.

No 1

B. BUSH. 31 Aug. 1849.

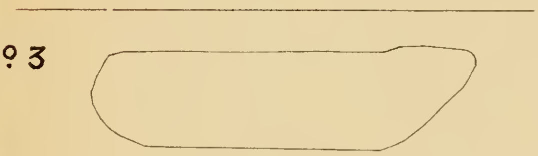
No 2



Before Alteration.

B. BUSH.

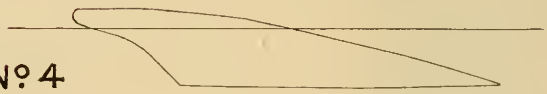
No 3



Bottom of Cylinder.

B. BUSH.

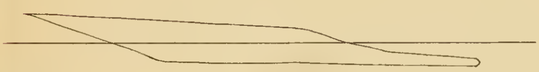
No 4



Top of Cylinder.

B. BUSH. Feb. 1850. After Alteration.

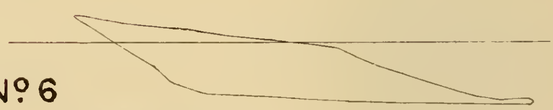
No 5



Working into Kirkdale Reservoir.

B. BUSH. 13 Dec. 1849. After Alteration.

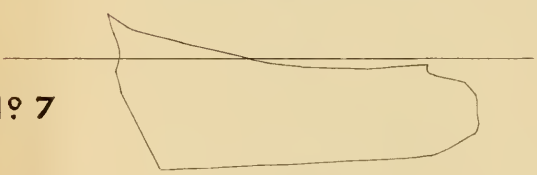
No 6



Hot Well 116°
Condensing Water 2½ Galls. per Stroke.

HOTHAM STREET.

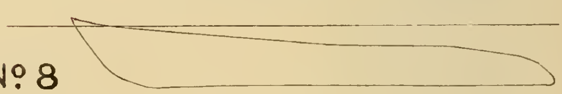
No 7



On Services.

HOTHAM St. Feb. 1850.

No 8

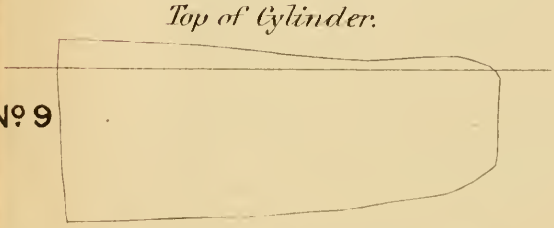


23 Strokes per Min. Working on Services.

WATER STREET.

Top of Cylinder.

No 9

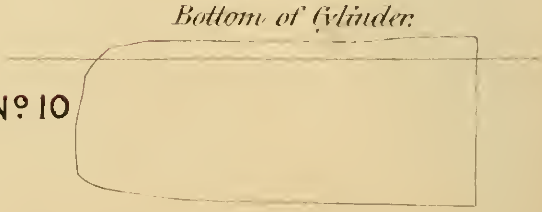


14 Strokes on Crosbie St. Tank.

WATER STREET.

Bottom of Cylinder.

No 10



14 Strokes on Crosbie St. Tank.

16 times from 10 lbs. to 35 lbs. on the square inch, equal to 33 feet to 90 feet on the main.

Soho.—When making 17 strokes showed 34 vibrations, between 95 and 125 lbs. per square inch, or 228 to 296 feet on the main.

Hotham Street.—Making 25 strokes showed 50 vibrations, from 40 to 75 lbs. per square inch, or from 101 to 181 feet on the main; and at 20 strokes gave 40 vibrations from 95 to 110 lbs., or 228 to 262 feet on the main; and it may be noticed that there is an air-vessel in the well here, as well as a stand-pipe on the surface, and the vibrations are as strong as in other instances.

Water Street.—At 16 strokes showed 32 vibrations, from 73 to 77 lbs. per square inch, or 177 to 186 feet on the main. Whether the close-topped pump forms an air-vessel may be considered in this case and in the Soho pump.

The pressure-gauge was connected to the main by a lead pipe, and was placed 10 to 12 feet above the street main. In the single-acting pump the vibration was coincident with the stroke, and the same with each delivery of the double-acting pumps.

Indicator diagrams are given from some of the cylinders of the above engines (Figs. 1 to 10, Plate XXXI.), and may prove useful in calculating the power expended under different conditions; but all such calculations are liable to error, owing to the absorption of power by the engine and pumps. The work done is given from experiments of long duration, and from the official records, as well as tables of known value, and may, therefore, be relied upon with confidence; but in any calculation, allowance must be made for the effect of vibrations and percussive force.

The cost of sinking wells and boring may be allowed to be inserted as an interesting note to the above remarks, and these are taken from Mr. Hughes' small work in Weales' Series.

Wells.	Truman's Brewery	196 ft.		£4,056 or	£21 per ft.
,,	Reid and Co.'s Brewery ...	259 ,,	*	7,454	29 ,,
,,	Zoological Gardens, Regent's Park	220 ,,		1,900	9 ,,
,,	Model Prison, Pentonville ...	220 ,,	× 6 ft.	1,300	6 ,,
,,	Colney Hatch Asylum ...	188 ,,		991	5 ,,
,,	Wolverhampton Waterworks	150 ,,	× 5 ,,		5 per yd.
Boring.	Lombard Street, E.C... ...	252 ,,		200	
,,	Water Lane, Edmonton ...	66 ,,		13	

* Reid and Co.'s well has four tunnels and cast iron tubbing.

Boring.	Waltham Abbey	90 ft.		£16
,,	Wigborough, Essex	300 ,,		120
,,	Mitcham	211 ,,		100
,,	Loughton, Essex	535 ,,		750
,,	Cambridge	150 ,,		20
,,	Green Lane Well, Liverpool ...	300 ,,	*	350
,,	Grenelle, Paris	1,798 ,,		14,500
,,	Kissengen, Bavaria	1,878 ,,		6,666

To the late Mr. James Newlands, Borough Engineer of Liverpool, and to Mr. John B. Palmer (who represented Mr. James Simpson, C.E.), the writer is indebted for much of the information given above; and the late Mr. Thomas Duncan, Engineer for the Corporation Water-works, also gave the result of subsequent working, which confirms the above statements, and places the Cornish engines, by Messrs. Harvey, of Hayle, at Green Lane, in even a better and more favourable position.

The PRESIDENT was sure they all felt very much indebted to Mr. Sanderson and to Mr. Waller for the careful manner in which they had prepared their papers. If any gentleman had any questions to ask Mr. Sanderson or Mr. Waller, they would be very ready to reply.

Mr. LAWRENCE might mention that with the firm of Messrs. James Simpson and Co., whose name had been mentioned by Mr. Waller, their rule was to make their air-vessel not only five times, as Mr. Sanderson had mentioned, but if possible fifteen times the contents of the working barrel. He ought to mention that, so far as his experience went, an air-vessel could not be made too large. He very much admired the means of charging an air-vessel pointed out by Mr. Sanderson. Their own plan used to be that of having a sniff-cock in between the two valves, but there was the disadvantage Mr. Sanderson pointed out—that the air had to rise up to get into the air-vessel, and also got mixed with the delivery. Now Mr. Sanderson admitted the air at the top of the air-vessel, and it simply came down and never mixed with the water, but was delivered into the air-vessel at the place where it was most required. This plan of air-vessel with internal pipe was not new. It had been in use in Cornwall, and was a very neat way of applying an air-vessel.

* The cost of the 6-inch bore-hole in the bottom of this well, 185 feet deep, was:—

£2 10s. 0d.	per yard for the first	20 yards.	
3 0 0	,,	second	,,
3 10 0	,,	third	,,
4 0 0	,,	fourth	,,
4 10 0	,,	fifth	,,

But there was one remark which Mr. Sanderson made which he certainly did not agree with, that was, that if the rising main was larger than necessary it put an additional pressure on the plunger. Again, he did not see how Mr. Sanderson could support his statement that half the water was delivered up into the air-vessel at each stroke. For instance, when the plunger came to the bottom of its stroke Mr. Sanderson stated half part of the water would go into the air-vessel, and the other half up the rising main; hence, the rising main might be proportionably decreased. Now he (Mr. Lawrence) thought that when the air-vessel had been at work for a few strokes the air was under a constant compression due to the pressure of the rising main; and hence, as soon as the plunger started it would still have that pressure to contend with, for when the delivery valve was open, the main being in free communication with the air-vessel, the pressure would be identical. When the plunger receded nothing further took place if that valve was in good order. He thought, therefore, that at the commencement of each stroke there was delivered into the air-vessel only a quantity of water which would be just as much as would overcome the blow of the pump and the friction of the column in the pipes. He might add that at Castle Eden Colliery a pumping engine had lately been erected underground, with four rams, working alternately with an air-vessel; and after they had been at work a short time the air-vessel blew off: since that time they had been working exceedingly well without one. The water delivered at the bank rose up several feet above the end of the pipe. In all cases where large quantities of water were delivered after an interval of rest, it was absolutely necessary to have as large an air-vessel as could be applied; but he thought that where water was delivered by a series of small pumps in small quantities, so as to keep the column in constant motion, there was not so much need of an air-vessel.

Mr. Sanderson—With regard to Mr. Lawrence's remark as to the size of the air-vessel, he thought there was a limit; for as the size increased, so did the necessity for strength in every part of the apparatus. The difficulty and cost of erection increased likewise, so that in water-works particularly, as in collieries, it was well to ascertain the reasonable minimum of the size and strength in any of the articles. No doubt, the air-vessel would be better if twice the diameter; but it would be much heavier and have other disadvantages in the room it would take up. He did not say it would be better to reduce it, except for the reasons he had stated. With regard to Mr. Lawrence's other question, he knew the quantity of water passing up the air-vessel by using a water-gauge outside the air-vessel, which showed exactly the separation between the water and the air; and as the rise at each stroke was exactly equal to one-half of that of the contents of the pump, he presumed that the other half had gone up the main. In the case he alluded to, the pressure was about 200 lbs. to the square inch.

Mr. Steavenson said, if he understood the two papers rightly, the last entirely answered the first. Mr. Waller stated there was no such thing as momentum in water when being pumped, and Mr. Sanderson's paper was entirely devoted to providing for that momentum, and preventing accidents from it. He should like, if they would allow him, to put his views into writing. Since he was here last month, he had read a paper on the momentum of pumping, and he found that the gentleman who read that paper before the South Wales Institute, had not only observed the momentum of water when raising it, and that the bucket carried that water above the pumps after the engine ceased to move; he had made a pump for the purpose of trying it, and found the results which he obtained were considerably more than he would have been led to expect, from the displacement of the bucket, entirely proving the views which he (Mr. Steavenson) had enunciated. There could be no doubt at all, that in raising, say, five tons of water, at a speed of five feet a second, a very large amount of *vis viva* was imparted to it; that *vis viva*, if unchecked, would continue to flow on after the engine stopped, so long as there was no friction to prevent it.

Mr. Waller thought that there were very few pumps worked at 5 or 6 feet a second, the usual speed would be only from 60 to 100 feet a minute, and to assume such a speed was to place upon the proceedings of the Institute an assumption contrary to fact.

The President asked Mr. Lawrence if he had ever had the opportunity of noticing an air-vessel horizontally laid instead of perpendicularly, and the effect of it?

Mr. Lawrence said, the effect of a horizontal air-vessel could not be so good as that of a vertical one, and it would be very much more difficult to keep supplied with air. In water-works, the great difficulty of making air-vessels was to get them so perfectly sound that the air at such high pressure would not pass through the pores of the cast iron. Hence it was, that unless the air-vessel could be charged either by the method pointed out by Mr. Sanderson, or some other, the air-vessel, with heavy pressures, became useless. He would like to ask Mr. Sanderson what pressure there was upon the Newburn engine when they made these experiments?

Mr. Sanderson—About 200 feet. There was a little difficulty in getting the pressure correct, as they were pumping against a loaded "balance valve," and not against a column of water in a pipe.

The PRESIDENT considered that the continuous supply of the four sets at Castle Eden quite justified Mr. Lawrence in leaving them without an air-vessel.

Mr. LAWRENCE would not like to say that there was no use in an air-vessel, even in pumps arranged as at Castle Eden, because he had not had an opportunity of finding out exactly what the air-vessel was doing before it was blown away. He was quite convinced that if they were to attempt to raise that quantity of water at one lift, it would be an impossibility to get anything to stand it, without the introduction of a perfect air-vessel, which he did not think they would be able to get at 155 fathoms.

The PRESIDENT asked if there had been an apparatus to supply the top air-vessel with?

Mr. LAWRENCE did not think there had. He had recommended them to have a pump put in, and he believed that Mr. Morison was invited to go out and make experiments; the experiments had not been made, but would be shortly, and he would communicate the results to the Institute.

Mr. SOUTHERN would like to ask Mr. Lawrence whether he would not get as good a result from the three pumps as from four, and if he could tell them the size of the plunger and of the pumps?

Mr. LAWRENCE'S answer to that question would be this:—In the case of the Castle Eden plungers, he believed there were four rams, each of ten inches. His own experience was, that, instead of pumping off the water at four intervals, if it could be done in twenty intervals during the same time it would be better, because there would not be the same strain on each point to contend with. If it had to be lifted at once, everything must be in proportion to the area in the large sized plunger. If four pumps or twenty are used, instead of one, there is, of course, only the area of these small plungers to deal with.

The PRESIDENT would now close the discussion, and at his suggestion, a cordial vote of thanks was given to Mr. Burdon Sanderson and to Mr. Waller for their very excellent papers.

The PRESIDENT announced that a subscription list had been opened, to defray the expense connected with inviting the Institution of Engineers and Shipbuilders in Scotland and the Lancashire and Cheshire Coal Association to Newcastle. £500 would be required, of which £260 had already been promised.

PROCEEDINGS.

GENERAL MEETING, SATURDAY, MAY 4, 1872, IN THE WOOD MEMORIAL HALL.

A. L. STEAVENSON, Esq., in the Chair.

The Secretary read the minutes of the last meeting and reported the proceedings of the Council.

The following gentlemen were elected, having been nominated at the April meeting:—

Members.

Mr. George William Hick, Mechanical Engineer, 17, Blenheim Terrace, Leeds.
Mr. Charles G. Grey, Dilston, Northumberland.
Mr. Matthew Robson, Coppa Colliery, near Mold, Flintshire.
Mr. Llewellyn Llewellyn, Colliery Manager, South Wales.
Mr. G. W. Wilkinson, Pensher Colliery, Fence Houses.

Student.

Mr. John James Parland, Mining Engineer, Burnopfield.

The following were nominated for election at the next meeting:—

Members.

Mr. Patrick Hill, Mining Engineer, Littleburn Colliery, Durham.
Mr. George Wright, Mining Engineer, Babbington Collieries, Cinder Hill, Nottingham.
Mr. E. B. Marten, C.E., Pedmore, Stourbridge.
Mr. M. W. Peace, Wigan, Lancashire.
Mr. Robert Nicholson, Engineer, Blaydon-on-Tyne.
Mr. Robert Tinsley, Agent, Seghill Colliery, near Newcastle-on-Tyne.

Students.

Mr. B. Fujimato, Engineer, 2, Bedford Place, Newcastle.
Mr. James Lisle, Washington Colliery, County of Durham.

The Chairman thought they might congratulate themselves on the increasing number of their members. He wished they could congratulate themselves also on the increasing numbers of those who attended the meetings.

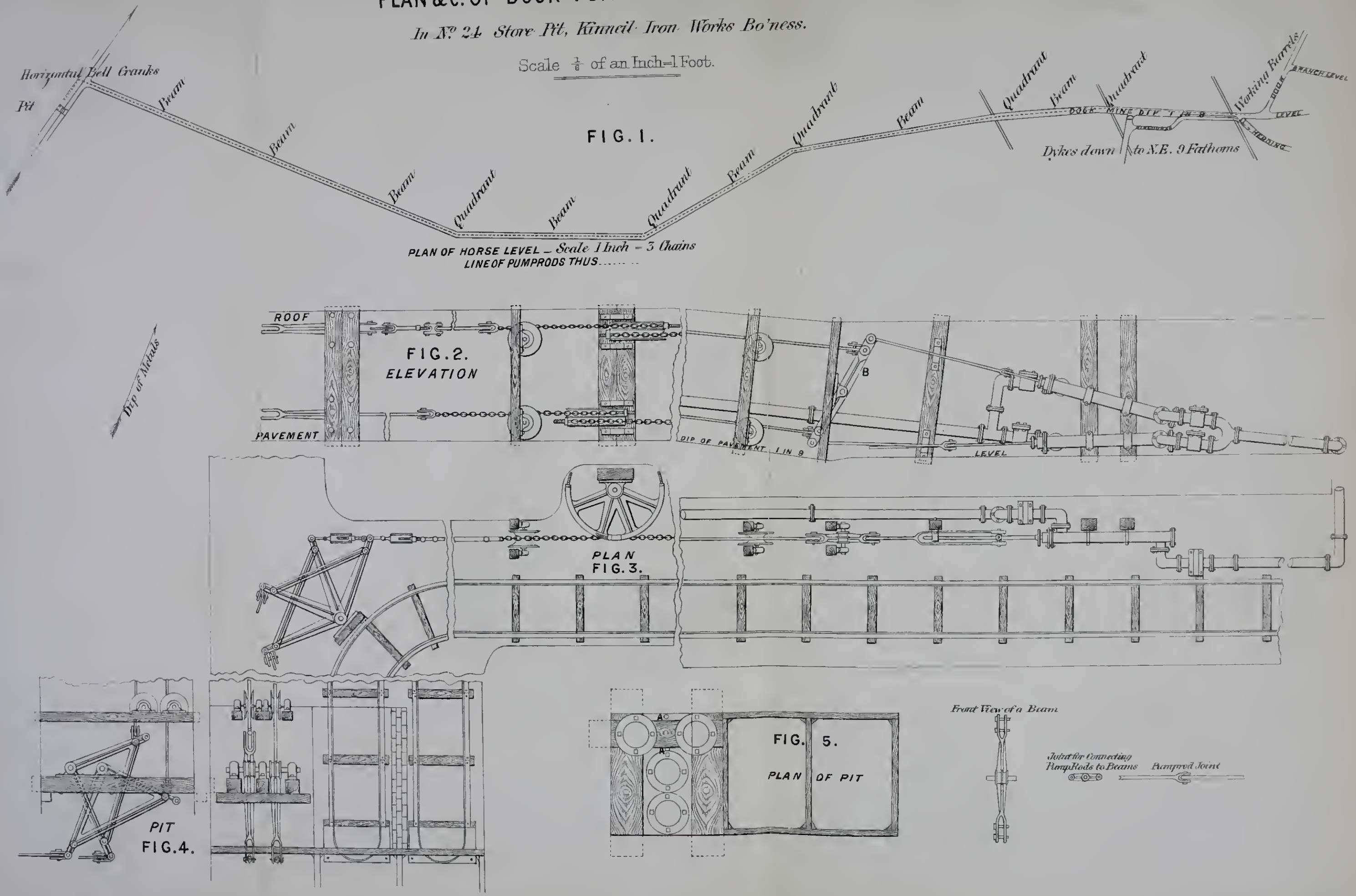
The following paper, by Mr. Ralph Moore, "Arrangements of Machinery adopted for Pumping Water in Dip Workings, at the Kinneil Iron Works, at a distance from the Shaft," was considered as read.


BRANCH LEVEL

PLAN &c. OF DOOK PUMPING ARRANGEMENTS,

In No. 24 Store Pit, Kinneil Iron Works Bo'ness.

Scale $\frac{1}{6}$ of an Inch = 1 Foot.



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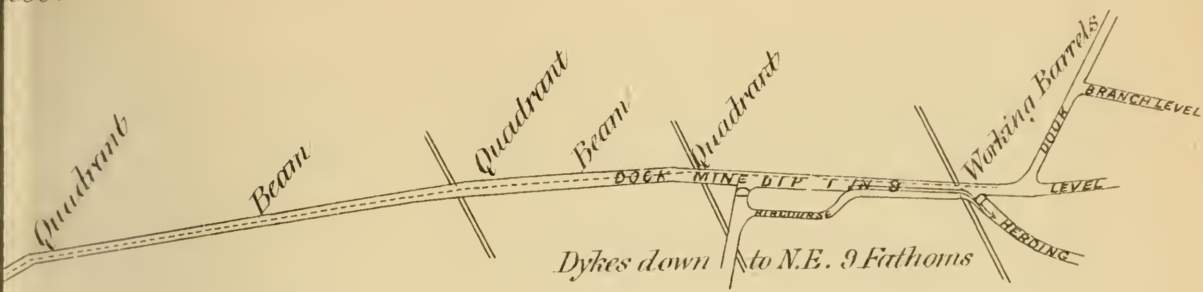
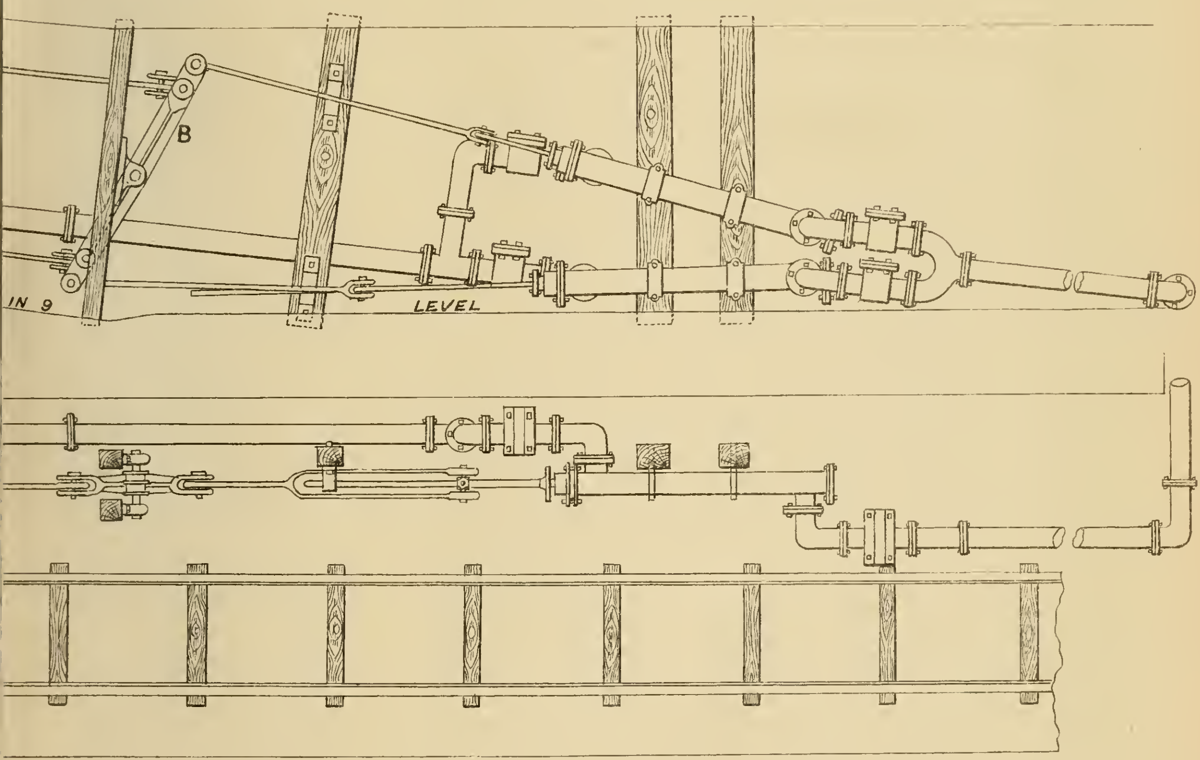
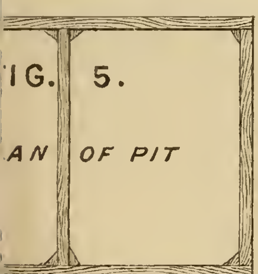
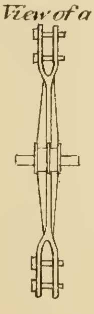






Front View of a Beam.



Joint for Connecting Pump Rods to Beams.

Pumprod Joint.

ARRANGEMENTS OF MACHINERY ADOPTED FOR PUMPING WATER IN DIP WORKINGS, AT THE KINNEIL IRON WORKS, AT A DISTANCE FROM THE SHAFT.

BY MR. RALPH MOORE.

IN writing the following paper, the author has endeavoured to show the arrangements of machinery adopted for pumping water in dip workings, at the Kinneil Iron Works, at a distance from the shaft.

Plate XXXII. represents the arrangements lately put up in No. 24 Store Pit, Kinneil Iron Works; but arrangements almost similar have been at work for a number of years back in three other pits in the same works.

The pumps are placed in the ironstone workings at a distance of 765 yards from the shaft, and the power is conveyed by a double set of iron rods attached to the dry rods in the pit, and carried into a beam, B, at that point which works the pumps. The rods are placed at each end of this beam, and each alternately draws it back, thus producing a reciprocating motion. The level road is crooked and uneven and the rods are carried in on quadrants, etc., as shown in the plate.

The water in the pit is raised to the surface by four 15-inch buckets worked by bell cranks. Of the two bottom sets each discharges the water into a lodgment made in splint coal 18 fathoms from the pit bottom, and the top sets deliver the water at 30 fathoms from lodgment in coal to an adit driven in fire-clay.

The small circles (AA, Fig. 5) show the position of dook rods in pit; the rods are of malleable iron, each 18 feet long and $1\frac{1}{2}$ inch in diameter (all the iron rods used being nearly of the same dimensions); they are connected by glands to the pit dry rods, one at 18 fathoms, and the other at 48 fathoms, and are conducted down the pit and connected there to the perpendicular cranks 5 feet 3 inches from the centres; the horizontal rods are connected 4 feet from the centres, which gives at the pit bottom nearly 3 feet stroke (the length of pumping engine stroke being 4 feet), which is further reduced so as to give 2 feet 6 inches stroke in dook pumps.

The iron rods from the perpendicular cranks are joined to the horizontal cranks at a distance of $10\frac{1}{2}$ fathoms from the pit bottom, the top rods being carried on pulleys at a gradual rise to the horizontal cranks placed 4 feet

7 inches, one above the other, to work the rods along the straight level mine, driven nearly at right angles to level from pit.

The rods being joined to each horizontal crank are carried on pulleys (placed 4 feet 7 inches, one above the other) along the side of the mine and level road for a distance of 291 fathoms to top of the dook, and are continued down the dook, dipping 1 in 9 for a distance of 81 fathoms to the working barrels, the rods being connected to the beam to work pumps, as shown in drawing.

There is connected to the same line of rods a $4\frac{1}{2}$ inch working barrel to pump a feeder of water that runs from the roof, about half-way down from top of dook mine ($4\frac{1}{2}$ fathoms). Pulleys for the support of iron pump rods are placed along the road nearly every 5 fathoms, beams every 50 fathoms, and quadrants at all the angles, as will be seen in plan of road.

The working barrels are each 6 inches inside diameter; the working pipes are each 4 inches inside diameter; length of stroke, 2 feet 6 inches, and number from 8 to 9 per minute, raising the water at present to the perpendicular height of 13 fathoms.

Level, from pit to top of dook, will average from $6\frac{1}{2}$ feet to 7 feet high by 6 feet to $6\frac{1}{2}$ feet wide; and dook, from 7 feet to $7\frac{1}{2}$ feet high by 9 feet wide.

These arrangements for pumping water in dip workings, work smoothly, and need very little attendance, the rods only requiring to be occasionally tightened by the screws when they become loose by friction, the greatest amount of friction being caused by the chains rubbing on the quadrants. It has been observed that the links wear very quickly where the angle is acute; and it is considered that it would be better in all acute angles where quadrants are used to adopt flat wire ropes instead of close-linked chains.

The pumps here are generally known by the name of Garibaldi pumps.

A number of years ago, in this same pit, a single wire rope was adopted, with back-balance, to pump water from a dook with one working barrel; but it was obliged to be abandoned, owing to the continual attendance and expense necessary to keep it in working condition. It worked best when the pump was going at the rate of 4 strokes per minute so long as the rope did not break, which was indeed very frequently the case; but when the motion was increased from 4 to 8 or 9 strokes, the friction, caused by the wire rope, wore the pulleys very rapidly, owing to the large quantity of back-balance weight required; and the rope being carried over pulleys in an unsteady, jerking motion, caused it to be almost daily necessary either to renew some of the pulleys, repair the rope, or refit some of the other parts of the machinery.

ON TEN YEARS' MINERAL STATISTICS OF THE UNITED KINGDOM.—1861 TO 1870.

By W. F. HOWARD, Chesterfield.

PRODUCTION.

It may well be thought by those most able to form competent judgment upon the matter, that the truly able and elaborate annual publication of the Keeper of Mining Records fulfils all requirements and needs no illustration.

Those rich quarries of facts do, indeed, illustrate themselves frequently and variously; but they are also suggestive of many valuable deductions unexpressed. They have furnished the whole of the data upon which the present paper is based; therefore, whatever practical or educational value attaches to the results of the writer's labours, obviously owes its origin to these national records that are inseparably associated with the name of Mr. Robert Hunt.

Where much may be inferred, something can be advantageously expressed; thus, in reviewing and comparing the statistics of a series of years, changes and results appear of national moment, which may be, to some persons, suggestive also of local and particular application.

To form standards of comparison by which the amount and values of the mineral productions of the United Kingdom, during ten recent years, are made to exhibit accurately the relative proportions of the several minerals raised, and of the districts furnishing contributions thereto, can but tend conveniently to elucidate the Mining Records.

Such has been the writer's aim, and hence the present synopsis, consisting of tables, to which the following explanation is intended to be simply introductory.

Mineral production is the only feature of the statistics at present attempted to be illustrated.

Value, and not quantity or tonnage, is solely considered in the tables, unless otherwise expressed, except in Table IV.

There are four series of tables herewith, numbered I., II., III., and IV.; each comprising ten years. Tables I., II., and III. contain, under the heads of each year, totals, and averages, per centages of values as will be described. The actual values upon which the per centages are based are given in Table I. In Table III. are given the actual values to which the per centages in that table and also in Table II. refer. The values in Table I. will be observed to be the totals of the other two tables last mentioned. The figures in Table IV. are tonnages and rates of value to which further reference will be made.

Confining remark at present to the per centage features of the tables, for Table I. the standard taken is, that the total annual value of all the minerals raised in the United Kingdom is represented invariably by 100·000. Whence is deduced the annual per centage value of each mineral, subdivided into the annual per centage value of each district's yield of such mineral.

Table I. is an abstract of the series, and shows the relative values of all the minerals to each other and to the total value, but omits details of districts: such details, it has been thought, will be found to be more usefully confined to bear reference to each mineral separately, as in the second series of tables.

For Table II., being the second series first mentioned, the standard taken is, that the total annual value of each mineral raised in the United Kingdom is represented invariably by 100·000; whence is deduced the annual per centage value of each mineral contributed by each district.

For Table III., or the third series, the standard taken is, that the total value of the production of each mineral separately, in each district separately, for the whole ten years' period is represented invariably by 1000·000; or in other words, that the *average* annual value is 100·000; whence is deduced the annual per centage value of each mineral, denoting clearly the stability of its yield, or the periods and amounts of its increase or decline, simultaneously with the state of progress of other districts.

In comparing the values of the different minerals before their conversion into metals and manufactured articles, it is evident that, between the ultimate value of the minerals and their apparent relative value taken simply as the produce of mining in the manner here represented, there may, and doubtless do, exist wide differences. With regard to coal, however, its low specific gravity or excess of bulk in proportion to weight, as compared with nearly all other minerals, must always make it the ruling mineral in this and every other highly-populated country (as well as on account of its furnishing the motive power of modern machinery, both stationary and for transit, and its use in converting all other minerals and itself into more finished articles), in respect of the superior facility and less cost with which materials of greater density can be transported. Hence, in great measure, the chief assemblages of manufacturing establishments and of populous places are upon and in contiguity to coal-fields; a rule that holds good throughout this country, except in such instances as the metropolis, where objects of national convenience and the extraneous tendencies of commerce prevail.

Restricting consideration to the apparent relative values,—the enormous preponderance of coal, 75 per cent., and of iron ore, 10 per cent. upon the total value of all the minerals raised during the ten years in value and also in tonnage (see Table IV.) over other minerals is strikingly exhibited. The annual, the ruling, and the recent rate and condition of development, decline, or fluctuation of the several mineral industries are made visibly clear, presenting interesting confirmation of known circumstances and interesting problems for enquiry. Thus, the vast and steady development of the coal trade, the more than doubled weight and value of iron ores production, the remarkable declension of copper, the steadiness of lead, and the variableness of tin, are most clearly indicated.

Confining attention to each mineral separately,—the changed and changing proportions contributed by each district to the national aggregate are highly instructive; and the more remote, the average and the present yields of different or competing districts are well calculated to convey just ideas of their relative importance. Of change, Table II., under head of Iron Ore, exhibits remarkable instances: thus, with Scotland, which in 1861 contributed 28½ per cent. of the annual national yield, falling to one-half of that quota in 1864–5, and to 9½ per cent. in 1866, being one-third of the proportion first mentioned. The recent rise of the same district in 1870 to 17⅔ per cent. is, if possible, even more noteworthy.

The decline of South Wales from 7½ to 4 per cent., with Monmouthshire included, and of South Staffordshire from 10 to 3 per cent., denote the present dependence of those great iron-making centres upon extraneous supplies and the effect of competition. The marvellous rush to the front of the North Riding or Cleveland District from 7¼ per cent. in 1861 to 19¼ per cent. in 1863, a position it has since more than maintained, shows how quickly dormant resources may be made to yield enormously. The too limited but most valuable hematite district of Cumberland, with part Lancashire, rivals its great Cleveland competitor: while the lias and oolite new ironstone fields of Lincolnshire and Northamptonshire, by having doubled and trebled respectively their former produce, give tokens of a greater future. Derbyshire, with its many new additional furnaces, shows a decline, having obtained supplies from these fields more advantageously than from its native ore. Durham and Northumberland from about an eighth of one per cent. have risen to $1\frac{1}{3}$ per cent. Cornwall is weakly represented in this metallic mineral only, having declined from ·4 to ·1; whilst Ireland from 0 had achieved ·4.

Of steady maintenance of general position, through great and almost continuous increase of production, coal affords illustration. Durham and Northumberland, averaging $24\frac{1}{4}$ per cent., show an increase from first to last of $2\frac{2}{3}$ per cent., namely, from $22\frac{1}{3}$ per cent. in 1861 to 25 per cent. in 1870. Scotland stands second at $13\frac{1}{4}$ on the average: then Lancashire, $12\frac{1}{2}$; Stafford and Worcester, $11\frac{3}{4}$; Yorkshire, 10; South Wales, $8\frac{1}{3}$; Derbyshire, $4\frac{7}{8}$; Monmouthshire, $4\frac{1}{3}$; and other districts of less importance, as shown in the table. The undeveloped Notts district of the great Midland Coal-field, having more than doubled its proportion, has responded to the introduction of capital in pits that have pierced the magnesian limestone.

Of lead, Durham and Northumberland have contributed on the average 24 per cent., Wales $27\frac{2}{3}$, Yorkshire 9, Cornwall $7\frac{2}{3}$, Derbyshire $6\frac{3}{4}$, Cumberland $6\frac{5}{8}$, Shropshire $4\frac{3}{4}$, Isle of Man $3\frac{2}{3}$, Westmorland $2\frac{1}{3}$, Scotland $2\frac{1}{2}$, Ireland $2\frac{1}{4}$ per cent.

Of tin, $98\frac{1}{2}$ per cent. was produced in Cornwall, and $1\frac{1}{2}$ in Devon.

Of copper, Cornwall yielded $58\frac{2}{3}$ per cent., Devonshire $17\frac{3}{4}$, Anglesea $3\frac{1}{3}$, Cheshire $1\frac{3}{4}$, Ireland 11 per cent.

Of zinc, $34\frac{1}{4}$ per cent. has come from the Isle of Man, $36\frac{1}{2}$ from Wales, $10\frac{1}{8}$ from Cornwall, $9\frac{1}{2}$ per cent. from Ireland.

Of iron pyrites, $67\frac{3}{4}$ per cent. was yielded by Ireland, $14\frac{1}{4}$ Cornwall, $6\frac{3}{4}$ Durham and Northumberland, $4\frac{1}{2}$ Yorkshire.

Of metallic minerals and earths, besides its contributions of tin, copper, lead, iron, zinc, and iron pyrites, Cornwall chiefly supplied manganese, arsenic, gossans, ochres, and umbers, and the whole of the small quantities of antimony, fluor spar, nickel ore, oxide of iron, tungstate of soda, uranium, and wolfram.

Of salt, Cheshire furnished $84\frac{3}{4}$ per cent., Worcestershire $13\frac{3}{4}$, Ireland $1\frac{1}{2}$ per cent.

Of fine and fire clays, Cornwall yielded in Porcelain clays 28½ per cent., Devon 7, Dorset 12, and the Midland District fire clays about 50 per cent.

The Eastern Counties, true to their agricultural character, contributed only coprolites manure.

Surrey yielded Fuller's earth.

Gold has been produced in Merionethshire and Sutherland, but of small amount; and in 1870 this mineral is unmentioned.

About half the produce of barytes is reported from Derbyshire; Northumberland and Shropshire next. The returns of this mineral and of some others have been evidently imperfect.

The instruction conveyed by the publication of grouped tabulated abstracts of estimates and returns of the national mineral production is most valuable in many ways and to many classes of persons. The localities from which supplies of the various minerals have been, are, and will probably hereafter be, derived, appear in evidence well calculated to command the attention of all who are, and of others who ought to be interested.

To mining and other engineers and students, geologists, property owners, agents, and financiers of all descriptions, statesmen and political economists, they convey information suggestive of direct application in their respective pursuits, and invite remunerative research.

From the exhaustive effect of mining operations upon the stores of mineral creation, from the ever increasing absorption of materials as civilization and inventions progress, from our growing population and consequently greater home consumption, and from the encouragement afforded of late years, at least to the present time, for export trade, the older and the more limited mining localities are being continually diminished in their natural resources, and inducement with necessity arises for the discovery and opening of new fields. Hence the appointment of the Royal Coal Commission, by whom the invaluable services of Mr. Hunt have been most judiciously applied in ascertaining the mineral position and prospects of other countries to afford evidence for judging of our own.

The conspicuous absence or insignificance of certain districts in relation to certain minerals invites investigation. Of this Ireland may be mentioned in illustration.

An examination of the results and tendencies of each mineral industry as a whole, and of each district contributing thereto, would be incomplete without comparison to a standard common to the series of years under consideration, and affecting each industry and district separately. The series of Tables III. are arranged to effect this object, and show both actual and per centage values, the former being here placed specially to prevent erroneous inferences, inasmuch as great per centage differences upon smaller values are balanced by less per centage differences upon larger values.

The actual values column in this table may be consulted in connection with the other tables. Without extracting instances in illustration it may suffice to direct attention more particularly to the districts and minerals previously mentioned as having changed or fluctuated the most. To quote instances, many of which will be found on examination of this table to be extremely forcible and interesting, might it is feared tend to confusion by appearing to conflict with the proportions quoted in showing the relations of particular districts to the general amount of all. It is evident, however, that there would be no discrepancy in reality.

In the Tables I., II., and III., hitherto particularized, value and not weight or tonnage has been adopted, from the convenience thus afforded by employment of the pound sterling (£) as a common denomination; upon which basis, comparisons of dissimilar materials, that would be impracticable or absurd upon a tonnage basis, are enabled to be made.

Table IV. gives the tonnages corresponding to the values in Table III., and shows the rate per ton at which the production of each mineral district has been taken.

The writer is perfectly aware that both the values adopted by Mr. Hunt, and the dissection of the same for districts by himself, are open to criticism, especially under the head of iron, for which reason indeed he has considered it proper to show the facts in their entirety. Another ground of objection is that the areas included in counties are not generally coincident with, or inclusive of entire mineral districts. To this, the writer can only say that he has endeavoured to use to the best advantage the materials at his command, and that he has followed the arrangement of the Government publication of Mineral Statistics.

Those acquainted with local facts may, where it is desirable to do so, be able, as they very probably will prefer, to adopt natural mineralogical divisions for distinction of districts.

There are other aspects and features of the Mineral Statistics of the Kingdom for the same period that the writer has now in hand to illustrate, but it has been thought undesirable to delay the present paper, particularly as its interest depends to a considerable extent upon the recency of the subject matter referred to.

TABLE I.

ANNUAL PER CENTAGE VALUE OF EACH MINERAL ON TOTAL ANNUAL VALUE OF MINERALS RAISED.

Mineral.	1861. Value.	1861. ℔ Cent.	1862. Value.	1862. ℔ Cent.	1863. Value.	1863. ℔ Cent.	1864. Value.	1864. ℔ Cent.
	£		£		£		£	
al	21,408,803	76·434	20,909,584	73·571	21,049,353	71·045	23,197,968	73·402
on Ore	2,302,371	8·220	2,399,739	8·443	3,240,890	10·939	3,367,144	10·654
n Ore	725,560	2·590	843,382	2·968	963,985	3·254	925,969	2·930
pper Ore ..	1,427,215	5·096	1,216,775	4·281	1,100,554	3·715	1,155,471	3·656
ad Ore	1,136,249	4·056	1,191,400	4·192	1,193,530	4·028	1,349,605	4·271
lver Ore	1,471	·005	15,095	·053	5,703	·019	38	..
nc Ore	31,113	·111	16,050	·056	29,968	·101	44,562	·141
on Pyrites ..	79,715	·285	58,213	·204	62,035	·209	58,097	·184
anganese ..	2,925	·010	..	..	..	..	..	..
rsenic	10,875	·039	820	·003	1,200	·004	1,393	·004
ossans, Ochres, Umbers, &c.	3,460	·013	5,000	·018	4·576	·015	2,759	·009
arytes	8,409	·030	7,319	·026	..	..	367	·001
prolites	75,000	·268	..	..	..	..	..	..
lt	..	..	..	..	..	..	..	..
ays, fine and fire	231,801	·827	272,799	·960	265,442	·896	368,315	1·165
ntimony	45	..	..	..	..	..	..	..
uor Spar ..	..	..	..	..	..	..	13	..
ickel Ore ..	24	..	..	..	..	..	..	..
ide of Iron ..	..	..	..	..	..	..	5	..
ngstate of Soda	..	..	..	..	..	..	..	..
ranium	..	..	..	..	23	..	..	..
olfram	29	..	63	..	67	..	14	..
old Quartz ..	10,000	·036	15,000	·053	1,500	·005	642	·002
ller's Earth ..	..	..	..	..	..	..	..	..
rthy Minerals..	554,460	1·980	1,469,882	5·172	1,709,558	5·770	1,131,685	3·581
Total	28,009,525	100·	28,421,121	100·	29,628,384	100·	31,604,047	100·

Mineral.	1865. Value.	1865. ℔ Cent.	1866. Value.	1866. ℔ Cent.	1867. Value.	1867. ℔ Cent.	1868. Value.	1868. ℔ Cent.
	£		£		£		£	
al	24,537,646	75·829	25,407,635	77·404	26,125,145	76·457	25,785,289	76·656
on Ore	3,324,804	10·275	3,119,098	9·502	3,210,098	9·395	3,196,600	9·503
n Ore	867,435	2·681	731,946	2·230	694,734	2·033	770,205	2·290
pper Ore ..	927,938	2·868	759,118	2·312	699,693	2·048	642,103	1·909
ad Ore	1,153,134	3·564	1,161,228	3·538	1,158,066	3·389	1,150,768	3·421
lver Ore	..	..	..	..	..	..	..	..
nc Ore	52,478	·162	42,655	·130	41,340	·121	39,191	·116
on Pyrites ..	71,174	·220	77,932	·237	67,453	·197	53,636	·159
anganese ..	..	..	..	..	3,232	·009	7,650	·023
rsenic	604	·002	1,301	·004	4,112	·012	9,710	·029
ossans, Ochres, Umbers, &c.	839	·003	3,049	·009	5,808	·017	6,372	·019
arytes	4,995	·015	1,751	·005	7,807	·023	8,728	·026
prolites	..	..	..	..	70,300	·206	71,500	·213
lt	..	..	..	..	836,963	2·449	927,227	2·756
ays, fine and fire	373,916	1·155	392,575	1·196	589,650	1·726	317,770	·945
ntimony	..	..	..	..	..	..	..	..
uor Spar ..	46	..	2	..	..	..	42	..
ickel Ore ..	..	..	..	..	14	..	..	..
ide of Iron ..	..	..	..	..	..	..	..	..
ngstate of Soda	..	..	..	..	..	..	..	..
ranium	..	..	..	..	..	..	..	..
olfram	11	..	..	..	62	..	67	..
old Quartz ..	..	..	..	..	5,320	·016	1,000	·003
ller's Earth ..	..	..	..	..	..	..	..	..
rthy Minerals..	1,044,085	3·226	1,126,322	3·433	650,000	1·902	650,000	1·932
Total	32,359,105	100·	32,824,612	100·	34,169,797	100·	33,637,858	100·

Mineral.	1869. Value.	1869. ℔ Cent.	1870. Value.	1870. ℔ Cent.	Total of 10 Years. Value.	Total of 10 Years. ℔ Cent.	Average. Value.	Average. ℔ Cent.
	£		£		£		£	
al	26,856,882	76·185	27,607,798	74·300	242,886,103	..	24,288,610	75·185
on Ore	3,732,560	10·588	4,951,220	13·331	32,844,524	..	3,284,452	10·167
n Ore	1,027,805	2·916	1,002,357	2·699	8,553,378	..	855,338	2·648
pper Ore ..	519,912	1·475	437,851	1·179	8,886,630	..	888,663	2·751
ad Ore	1,189,030	3·373	1,200,209	3·231	11,883,219	..	1,188,322	3·678
lver Ore	..	..	..	..	22,307	..	2,231	·007
nc Ore	49,366	·140	41,058	·110	387,781	..	38,778	·120
on Pyrites ..	41,023	·116	36,026	·097	605,304	..	60,530	·187
anganese ..	7,897	·022	19,499	·052	41,203	..	4,120	·013
rsenic	11,464	·033	17,739	·048	59,218	..	5,922	·018
ossans, Ochres, Umbers, &c.	4,943	·014	4,261	·011	41,067	..	4,107	·013
arytes	3,415	·010	3,771	·010	46,562	..	4,656	·015
prolites	..	..	50,000	·135	266,800	..	26,680	·083
lt	687,500	1·950	744,725	2·005	3,196,415	..	319,641	·990
ays, fine and fire	450,000	1·276	450,000	1·212	3,712,268	..	371,228	1·149
ntimony	..	..	..	..	45	..	5	·000
uor Spar ..	..	..	..	..	103	..	10	·000
ickel Ore ..	..	..	27	..	65	..	7	·000
ide of Iron ..	..	..	..	..	5	..	..	·000
ngstate of Soda	212	·001	379	·001	591	..	59	·000
ranium	..	..	..	..	23	..	2	·000
olfram	111	..	274	·001	698	..	70	·000
old Quartz ..	..	..	..	..	33,462	..	3,346	·010
ller's Earth ..	..	..	..	..	..	..	..	..
rthy Minerals..	670,000	1·901	575,000	1·548	9,580,992	..	958,099	2·966
Total	35,252,120	100·	37,142,194	100·	323,048,763	1000·	32,304,876	100·

This paper was accompanied with diagrams illustrating the tables; these diagrams have not been published.

TABLE II.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

COAL.

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Durham and Northumberland..	22·356	23·148	25·093	25·097	25·505	24·790	23·797	23·651	23·984	25·005	1865	25·505	1861	22·356	24·269
Cumberland..	1·466	1·591	1·503	1·488	1·458	1·466	1·447	1·336	1·313	1·275	1862	1·591	1870	1·275	1·427
Yorkshire	10·947	11·066	10·650	9·494	9·531	9·559	9·420	9·444	10·081	9·605	1862	11·066	1867	9·420	9·932
Derbyshire	5·975 (Derbyshire and Notts)	5·422	5·154	4·818	4·682	4·674	4·355	4·807	5·083	4·620	1862	5·422	1867	4·355	4·890
		..	..	..	..	..	..	..	..	..	..	..	..	..	− ·096
Notts		·876	·849	·859	1·116	1·575	1·507	1·462	1·467	1·916	1870	1·916	1863	·849	1·340
Leicestershire	·864	·832	·913	·960	·984	·853	1·100	·589	·606	·543	1867	1·100	1870	·543	·817
Warwickshire	·756	·811	·776	·813	·875	·762	·843	·606	·545	·586	1865	·875	1869	·545	·732
Staffordshire and Worcestershire	10·806	11·386	11·177	12·350	12·431	12·101	11·987	11·920	11·793	11·981	1865	12·431	1861	10·806	11·823
Lancashire	14·241	12·670	12·318	12·426	12·188	12·125	12·288	12·413	13·028	12·506	1861	14·241	1866	12·125	12·601
Cheshire	·936	·942	·932	·887	·866	·881	·895	·909	·891	·842	1862	·942	1870	·842	·896
Shropshire	·969	1·231	1·303	1·239	1·156	1·201	1·491	1·450	1·297	1·216	1867	1·491	1861	·969	1·261
Gloucestershire	..		..	..	..	1·821 (Gloucestershire and Somersetshire)	1·890	1·909	1·843	1·771					
Somersetshire	..	2·092 (Gloucestershire, Somersetshire and Devonshire)	2·209	2·101	1·910	..	..	..	..	..	1863	2·209	1870	1·771	1·963
Devonshire	7·603 (Gloucestershire to Monmouthshire)	..	..	..	..	..	..	..	..	..	..	..	..	..	+ ·043
Monmouthshire	..	4·484	4·615	4·341	4·203	4·374	4·373	4·121	3·979	3·952	1863	4·615	1870	3·952	4·311
South Wales	7·813	8·070	7·834	7·488	8·061	9·226	8·701	8·686	8·545	8·421	1866	9·226	1864	7·488	8·317
North Wales	2·184	1·984	1·957	2·141	2·020	2·048	2·269	2·312	2·006	2·109	1868	2·312	1863	1·957	2·107
Scotland	12·940	13·243	12·573	13·363	12·888	12·422	13·517	14·262	13·420	13·524	1868	14·262	1866	12·422	13·237
Ireland	·144	·152	·144	·135	·126	·122	·120	·123	·119	·128	1862	·152	1869	·119	·130
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	..	..	..	..	100·

TABLE II.—Continued.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

IRON ORE.

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Sundry doubtful	..	..	3·667	..	4·199	..	..	..	..	..	1865	4·199	..	Nil.	·787
Ireland	·003	·252	·342	·604	·247	·170	·331	·328	·327	·392	1864	·604	1861	·003	·316
Scotland	28·594	20·836	16·199	16·621	11·053	12·720	9·694	9·541	13·061	17·672	1861	28·594	1868	9·541	15·180
Isle of Man	·035	·011	·006	..	·002	..	..	·002	·027	..	1861	·035	..	Nil.	·008
North Wales	·974	·595	·308	·292	·887	·545	·378	·330	·279	·419	1861	·974	1869	·279	·478
South Wales	7·483	6·220	5·168	5·506	3·867	4·169	4·088	3·297	4·839	2·686	1861	7·483	1870	2·686	4·516
Monmouthshire	..	..	..	..	·001	·000	2·680	2·736	3·282	1·272	1869	3·282	..	Nil.	1·094
Durham and Northumberland	·130	·143	1·157	1·564	·902	·874	·990	·978	1·068	1·390	1864	1·564	1861	·130	·991
Yorkshire { West Riding	2·557	3·651	3·664	3·378	4·324	2·862	4·509	6·144	1·547	1·554	1868	6·144	1869	1·547	3·312
Yorkshire { North Riding	7·356	10·560	19·243	20·737	22·974	23·763	24·861	21·956	20·728	20·649	1867	24·861	1861	7·356	19·925
Cumberland	11·279	12·776	12·791	15·731	15·405	17·254	17·737	19·094	19·650	18·226	1869	19·650	1861	11·279	16·369
Lancashire	11·275	11·655	10·161	10·267	9·135	10·992	10·395	12·007	10·509	13·208	1870	13·208	1865	9·135	11·036
Derbyshire	4·306	3·599	2·704	2·417	2·632	2·641	2·726	2·874	2·358	2·720	1861	4·306	1869	2·358	2·821
South Staffordshire	9·874	10·582	9·180	8·329	5·703	5·281	4·251	2·719	2·579	3·181	1862	10·582	1869	2·579	5·757
North Staffordshire	7·588	9·422	7·580	5·182	8·333	6·622	6·611	6·709	8·625	6·434	1862	9·422	1864	5·182	7·221
Warwickshire	·174	·154	·097	·117	·124	·150	·121	·116	·100	·124	1861	·174	1869	·100	·125
Shropshire	2·102	2·035	1·907	1·877	2·059	2·292	1·947	2·178	2·133	2·387	1870	2·387	1864	1·877	2·107
Lincolnshire	·582	·868	·859	·531	·893	1·338	1·497	1·609	1·684	1·191	1869	1·684	1864	·531	1·135
Northamptonshire	1·239	1·331	1·285	2·517	2·891	3·813	3·246	3·512	3·619	3·844	1870	3·844	1861	1·239	2·874
Oxfordshire	·091	·051	·059	·079	·026	·017	..	..	·068	·196	1870	·196	..	Nil.	·066
Hampshire	·074	·065	·021	·069	·052	..	..	..	..	..	1861	·074	..	Nil.	·024
Wiltshire	1·151	·948	·896	·949	·930	·970	1·029	9·40	1·123	·512	1861	1·151	1870	·512	·919
Herefordshire	..	..	..	..	·003	·002	..	..	..	..	1865	·003	..	Nil.	·001
Gloucestershire	1·963	3·075	1·771	1·896	2·075	2·340	2·189	2·357	2·075	1·668	1862	3·075	1870	1·668	2·094
Somersetshire	·712	·633	·535	·798	·571	·566	·559	3·81	·214	·140	1864	·798	1870	·140	·479
Devonshire	·094	·085	·057	·157	·393	·401	·099	·115	·057	·070	1866	·401	1869	·057	·151
Cornwall	·364	·453	·343	·382	·319	·218	·062	·077	·048	·065	1862	·453	1869	·048	·214
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	..	..	..	..	100·

TABLE II.—CONTINUED.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

TIN ORE.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Cornwall	97·721	98·242	97·992	97·766	98·139	98·606	99·247	99·519	98·945	99·661	1870	99·661	1861	97·721	98·586
Devonshire	2·279	1·758	2·008	2·234	1·861	1·394	·753	·481	1·055	·339	1861	2·279	1870	·339	1·414
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·					100·

ZINC ORE.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Cornwall	37·062	12·548	10·408	4·831	5·311	7·727	10·204	14·026	4·353	6·147	1861	37·062	1869	4·353	10·132
Devonshire	·354	·262	·731	·298	·175	·553	·585	·439	·508	2·363	1870	2·363	1865	·175	·636
Cumberland	3·593	5·938	4·271	3·573	3·464	3·015	4·026	3·411	4·082	4·236	1862	5·938	1866	3·015	3·817
Derbyshire	5·907	17·134	6·257	5·368	2·858	1·758	·247	·329	·253	·480	1862	17·134	1867	·247	3·006
Shropshire	..	..	1·752	·936	1·073	·954	3·082	1·643	·478	3·105	1870	3·105	..	..	1·377
Staffordshire	..	..	..	..	·238	1·282	·576	·311	2·253	·638	1869	2·253	..	..	·620
Wales. Anglesea	..	..	1·839	..	..	..	..	..	..	..	1863	1·839	..	..	·142
Wales. Brecknockshire	..	..	..	..	..	..	..	..	..	·402	1870	·402	..	..	·043
Wales. Carnarvon	..	1·570	·007	·101	..	..	..	·046	..	·519	1862	1·570	..	..	·137
Wales. Denbighshire	6·026	11·221	9·840	19·793	23·092	28·864	23·041	31·278	18·954	22·088	1868	31·278	1861	6·026	20·652
Wales. Flintshire	7·531	11·277	3·837	2·450	2·691	3·941	12·579	19·788	15·008	16·469	1868	19·788	1864	2·450	9·442
Wales. Montgomery	..	..	..	..	·471	·134	1·434	1·077	·594	5·792	1870	5·792	..	..	1·029
Wales. Merionethshire	..	..	..	..	·452	..	..	..	..	..	1865	·452	..	..	·061
Wales. Cardiganshire	14·190	3·888	omitted	1·120	4·381	·544	1·168	·452	·357	1·293	1861	14·190	1869	·357	2·433
Wales. Caermarthen	..	1·433	8·432	8·467	3·935	2·766	..	..	..	·492	1864	8·467	..	..	2·573
Wales. Pembrokeshire	..	..	..	..	..	..	..	·393	..	..	1868	·393	..	..	·040
Isle of Man	19·616	8·611	18·536	32·384	36·087	44·302	42·020	26·179	52·698	33·694	1869	52·698	1862	8·611	34·243
Ireland (Tipperary)	5·721	26·118	34-090	20·679	15·511	3·175	1·038	·628	·389	2·282	1863	34·090	1869	·389	9·464
Scotland	..	..	..	..	·261	·985	..	..	·073	..	1866	·985	..	..	·153
Total	100·	100·	100.	100·	100·	100·	100·	100·	100·	100·					100·

TABLE II.—CONTINUED.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL

COPPER ORE.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Cornwall	56·438	59·854	58·420	57·113	61·708	56·788	59·151	58·091	60·850	55·322	..	..	..	..	58·355
Devonshire	15·132	16·523	17·192	16·807	19·913	19·955	20·692	20·051	16·625	19·206	..	..	..	..	17·788
Cumberland	·068	·025	..	..	·019	·027	·055	·093	·111	·134	..	..	..	..	·043
Lancashire	1·198	1·566	1·387	1·195	1·312	1·465	1·499	1·091	1·279	1·275	..	..	..	..	1·331
Yorkshire	..	..	..	·044	·043	..	..	..	..	·072	..	..	..	..	·014
Cheshire	1·290	1·305	1·363	1·298	1·606	2·012	2·358	1·830	2·037	6·128	..	..	..	..	1·802
Shropshire	..	..	..	..	..	·027	·109	·015	..	..	..	..	..	..	·012
Staffordshire	..	..	..	·011	..	..	·010	..	..	·004	..	..	..	..	·004
Wales: Cardiganshire	·045	·215	..	·246	·279	·177	·150	·101	·190	·186	..	..	..	..	·153
Wales: Carnarvon	·329	·397	·270	..	·471	·184	·700	·121	·320	·385	..	..	..	..	·307
Wales: Flintshire	..	..	·024	..	..	·001	..	..	..	..	..	..	..	..	·003
Wales: Montgomery	·049	..	..	·048	..	..	..	·238	·114	·102	..	..	..	..	·043
Wales: Anglesea	1·177	2·593	2·588	2·264	4·195	6·414	2·959	5·441	4·051	6·432	..	..	..	..	3·325
Isle of Man	·615	·411	·542	·049	·865	·119	·200	·323	·414	·378	..	..	..	..	·411
Ireland: Cork	4·907	6·104	6·913	6·094	5·200	5·169	6·048	4·614	5·681	2·497	..	..	..	..	5·522
Ireland: Waterford	4·305	3·828	4·310	4·104	3·322	6·470	5·499	7·460	5·757	2·269	..	..	..	..	4·603
Ireland: Wicklow	·138	·138	·233	·376	·710	·861	·226	·055	1·303	3·420	..	..	..	..	·533
Ireland: Kerry	·110	·247	..	..	..	..	..	..	..	..	..	..	..	..	·051
Sundries undivided under 5 tons	14·076	6·723	6·758	10·351	·349	·331	·344	·452	1·268	2·190	..	..	..	..	5·670
Scotland (Renfrew)	·123	·071	..	..	·008	..	..	..	..	..	..	..	..	..	·030
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	..	..	..	..	100·

TABLE II.—Continued.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

LEAD ORE.

Districts	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Greatest		Least		Average
Cornwall	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Devonshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Somersetshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Derbyshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Staffordshire	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Shropshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cheshire	[illegible]										[illegible]	[illegible]			[illegible]
Lancashire						[illegible]	[illegible]	[illegible]			[illegible]	[illegible]			[illegible]
Yorkshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cumberland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Westmoreland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Durham and Northumberland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Carnarvon	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Denbighshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Flintshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Montgomery	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Merionethshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]
Wales: Cardigan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Carmarthen	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Pembrokeshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Wales: Brecknock		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]			[illegible]
Wales: Radnorshire	[illegible]										[illegible]	[illegible]			[illegible]
Isle of Man	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Ireland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Scotland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Sundries under 10 tons	[illegible]	[illegible]	[illegible]								[illegible]	[illegible]			[illegible]
Total	100	100	100	100	100	100	100	100	100	100					100

TABLE II.—*Continued.*

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

IRON PYRITES.

Districts.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Greatest.		Least.		Average.
Cornwall	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Devonshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cumberland	[illegible]	[illegible]	[illegible]	[illegible]							[illegible]	[illegible]			[illegible]
Durham and Northumberland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Yorkshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lancashire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Shropshire										[illegible]	[illegible]	[illegible]			[illegible]
Anglesea			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]
Carnarvon	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
Montgomeryshire										[illegible]	[illegible]	[illegible]			[illegible]
Denbighshire and Flintshire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]			[illegible]
Ireland, Wicklow	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total	100	100	100	100	100	100	100	100	100	100					100

MANGANESE.

Districts.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Greatest.		Least.		Average.
Cornwall and Devonshire	100						[illegible]	100	100	100					
Carnarvon							[illegible]								
Merionethshire							[illegible]								
Total	100						100	100	100	100					

TABLE II.—Continued.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

ARSENIC.

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.
Cornwall	..	100·	..	..	100·	100·	50·438	37·158	32·606	29·212
Devonshire	..	..	..	..	..	..	·924	28·857	67·394	70·788
Produced at Swansea	..	..	..	..	..	..	..	33·985	..	..
Estimated	..	..	..	..	..	..	48·638	..	..	..
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·

N.B.—Returns imperfect.

GOSSANS, OCHRES, UMBERS, &c.

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.
Cornwall	87·168	100·	49·410	23·523	100·	44·769	16·237	20·355 }	5·199	3·333
	..	..	..	..	..	..	..	15·694 }	..	..
Devonshire	..	..	2·185	2·356	..	1·607	·981	·989 }	2·569	·798
Isle of Man	12·832	..	..	..	..	2·460	..	8·192	11·309	7·862
Anglesea	..	..	48·405	74·121	..	51·164	82·782	54·770	}	
Pt. Cornwall...	..	..	..	..	..	..	..	..	} 80·923	88·007
Pt. Devonshire	..	..	..	..	..	..	..	..	}	
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·

N.B.—Returns imperfect.

TABLE II.—CONTINUED.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

BARYTES.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Northumberland	..	..	..	..	..	..	44·178	10·988	45·095	45·028	..	..	..	..	16·421
Durham	..	..	..	..	60·560	..	..	..	..	..	..	..	..	..	6·497
Cumberland	·488	·150	..	3·542	1·601	7·082	4·932	1·501	2·928	9·069	..	..	..	..	2·571
Yorkshire	6·945	5·014	..	..	..	..	..	..	..	..	..	..	..	..	2·043
Derbyshire	65·501	64·462	..	..	..	..	39·106	71·517	43·016 Wardlow omitted	37·921	..	..	..	..	48·151
Shropshire	·737	7·501	..	96·458	38·439	92·918	11·784	15·994	7·292	7·982	..	..	..	..	15·845
North Wales	14·806	9·537	..	..	..	..	..	..	..	..	..	..	..	..	4·173
Montgomery	..	..	..	..	..	..	..	..	1·669	..	..	..	..	..	·122
Scotland } Kirkcudbright	1·522	1·503	..	..	..	..	..	..	..	..	..	..	..	..	·511
Isle of Arran	5·458	7·324	..	..	..	..	..	..	..	..	..	..	..	..	2·137
Ireland	4·543	4·509	..	..	..	..	..	..	..	..	..	..	..	..	1·529
Total	100·	100·	..	100·	100·	100·	100·	100·	100·	100·	..	..	..	..	100·

COPROLITES.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Bedfordshire	..	..	..	..	..	..	18·919	20·	..	..	..	..	..	..	..
Cambridgeshire } Hertfordshire } Suffolk	100·	..	..	..	..	..	81·081	80·	..	..	..	..	..	..	..
Estimated	..	..	..	..	..	..	..	..	..	100·	..	..	..	..	..
Total	100·	..	..	..	..	..	100·	100·	..	100·	..	..	..	..	..

TABLE II.—Continued.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

SALT.

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Cheshire	...	...	...	...	...	...	89·610	82·571	83·002	83·924	1867	89·610	1868	82·571	84·822
Worcestershire	...	...	...	...	...	...	8·979	15·854	15·600	14·770	1868	15·854	1867	8·979	13·747
Ireland	...	...	...	...	...	...	1·411	1·575	1·398	1·306	1868	1·575	1870	1·306	1·431
Total	N.B.—Returns vague, and undistinguished in Summary. ...	...	...	...	...	...	10)·	100·	100·	100·	...	...	...	...	100·

CLAYS (FINE AND FIRE).

District.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.	Greatest.		Least.		Average.
Cornwall	30·323	26·414	27·127	28·502	29·573	31·843	24·372	36·322	26·712	28·390	1868	36·322	1867	24·372	28·608
Devonshire	7·513	5·623	6·435	6·981	6·876	7·628	5·365	9·394	6·530	7·072	1868	9·394	1867	5·365	6·840
Dorsetshire	24·451	22·137	19·347	13·609	13·406	12·768	6·360	1·180	...	8·333	...	...	...	...	11·719
Staffordshire	21·050	...	...	...	...	...	...	...	...	...	...	...	...	...	
Yorkshire	13·481	...	...	...	...	...	...	...	...	...	...	...	...	...	
		45·821	47·091	50·908	50·145	47·761	31·798	53·104	66·758	...	...	...	...	...	47·733
Derbyshire	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	3·182														
Do. (adjacent counties) ...	...	...	...	...	...	...		...	...	56·205	...	...	...	...	
Sundry	...	...	...	...	...	...	32·105	...	...	...	...	...	...	...	5·100
Total	100·	100·	100·	100·	100·	100·	100·	100·	100·	100·	...	...	...	...	100·

TABLE II.—CONTINUED.

PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL ANNUAL VALUE OF EACH MINERAL.

N.B.—Very small Values of Sundry Minerals were returned in the years, and as shown below.

DISTRICT.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	1869.	1870.
Cornwall, viz. :—										
Antimony	—									
Fluor spar	...	...	...	—	—	—	...	—		
Nickel ore	—	...	...	...	...	...	—	...	...	(Scotland.) —
Oxide of iron ...	...	...	...	—						
Tungstate of soda	...	...	...	...	...	...	...	...	—	—
Uranium	...	...	—							
Wolfram	—	—	—	—	—	...	—	—	—	—
Gold quartz—										
Merionethshire ...	—	—	—	—	—	—	—	—	—	
Sutherlandshire ..	...	...	...	...	...	...	...	...	—	
Fuller's earth—										
Surrey	—	—								
Earthy Minerals of considerable aggregate value	—	—	—	—	—	—	—	—	—	—

TABLE III.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

COAL.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Durham and Northumberld.	4,786,241	81·196	4,840,089	82·109	5,281,774	89·602	5,822,092	98·768	6,258,173	106·166	6,298,637	106·852	6,216,868	105·465	6,098,542	103·458	6,441,357	109·273	6,903,385	117·111	58,947,158	..	5,894,716	24·269
Cumberland ..	313,911	90·570	332,572	95·956	316,458	91·306	345,199	99·598	357,762	103·223	372,620	107·510	378,129	109·099	344,506	99·398	352,702	101·763	352,059	101·577	3,465,918	..	346,592	1·427
Yorkshire	2,343,650	97·150	2,313,875	95·915	2,241,652	92·921	2,202,400	91·295	2,338,775	96·947	2,428,675	100·674	2,460,896	102·010	2,435,127	100·941	2,707,456	112·230	2,651,651	109·917	24,124,157	..	2,412,416	9·932
Derbyshire	..	..	1,133,700	95·442	1,084,945	91·337	1,117,687	94·094	1,148,937	96·725	1,187,630	99·982	1,137,638	95·773	1,239,470	104·346	1,365,022	114·916	1,275,566	107·385	10,690,595	..	1,187,844	4·890
(Derbyshire and Notts)	1,279,080	85·853																			1,279,080	..	− 23,418	− ·096
Notts ..	..	..	183,166	56·287	178,807	54·948	199,175	61·206	273,875	84·162	400,140	122·963	393,750	121·000	377,110	115·886	393,862	121·034	528,843	162·514	2,928,728	..	325,414	1·340
Leicestershire ..	185,000	93·255	174,006	87·713	192,099	96·834	222,625	112·221	241,375	121·673	216,640	109·204	287,500	144·924	152,022	76·631	162,675	82·002	149,862	75·543	1,983,804	..	198,380	·817
Warwickshire ..	161,750	91·054	169,500	95·418	163,430	92·001	188,500	106·113	214,750	120·891	193,750	109·069	220,213	123·966	156,215	87·939	146,407	82·418	161,885	91·131	1,776,400	..	177,640	·732
Staffordshire and Worcestershire	2,313,437	80·561	2,380,683	82·902	2,352,772	81·930	2,864,963	99·766	3,050,247	106·218	3,074,645	107·067	3,131,640	109·052	3,073,695	107·034	3,167,276	110·293	3,307,516	115·177	28,716,879	..	2,871,688	11·823
Lancashire ..	3,048,875	99·616	2,649,375	86·563	2,592,831	84·716	2,882,500	94·180	2,990,500	97·709	3,080,125	100·637	3,210,380	104·893	3,200,125	104·558	3,498,875	114·319	3,452,650	112·809	30,606,236	..	3,060,624	12·601
Cheshire	200,392	92·124	196,937	90·535	196,152	90·174	205,687	94·558	212,500	97·690	223,875	102·920	233,750	107·460	234,375	107·747	239,287	110·005	232,287	106·787	2,175,242	..	217,524	·896
Shropshire	207,438	67·723	257,437	84·047	274,171	89·511	287,500	93·862	283·750	92·638	305,175	99·632	389,625	127·203	373,875	122·061	348,215	113·684	335,825	109·639	3,063,011	..	306,301	1·261
Gloucestershire			..	..	..	..	..	..	..	..														
Somersetshire ..	..	..	437,500	91·756	464,900	97·502	487,500	102·242	468,750	98·309	462,675	97·036	493,750	103·553	492,250	103·238	494,987	103·812	488,978	102·552	4,291,290	..	476,810	1·963
(Gloucestershire, Somersetshire and Devonshire)	1,627,756	106·094	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,627,756	..	+ 10,389	+ ·043
Devonshire ..	..	..																						
Monmouthshire	..	..	937,500	89·537	971,522	92·786	1,007,125	96·186	1,031,250	98·490	1,111,250	106·131	1,142,376	109·103	1,062,625	101·487	1,068,787	102·075	1,091,085	104·205	9,423,520	..	1,047,058	4·311
South Wales ..	1,672,693	82·802	1,687,364	83·529	1,649,103	81·635	1,737,000	85·986	1,977,877	97·910	2,344,111	116·040	2,273,077	112·523	2,239,875	110·880	2,294,912	113·604	2,324,943	115·091	20,200,955	..	2,020,095	8·317
North Wales ..	467,562	91·363	415,000	81·092	411,973	80·500	496,765	97·069	495,750	96·870	520,500	101·706	592,813	115·837	596,250	116·508	538,795	105·281	582,257	113·774	5,117,665	..	511,766	2·107
Scotland	2,770,250	86·163	2,769,000	86·124	2,646,474	82·313	3,100,000	96·419	3,162,500	98·363	3,156,250	98·168	3,531,490	109·839	3,677,490	114·380	3,604,287	112·104	3,733,638	116·127	32,151,379	..	3,215,138	13·237
Ireland	30,768	97·265	31,875	100·765	30,290	95·754	31,250	98·789	30,875	97·604	30,937	97·800	31,250	98·790	31,737	100·329	31,980	101·097	35,368	111·807	316,330	..	31,633	·130
Total	21,408,803	88·144	20,909,584	86·088	21,049,353	86·664	23,197,968	95·510	24,537,646	101·025	25,407,635	104·607	26,125,145	107·561	25,785,289	106·162	26,856,882	110·574	27,607,798	113·665	242,886,103	..	24,288,610	100·

TABLE III.—Continued.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

IRON ORE.

District.	1861.		1862.		1863.		1864.		1865.	
	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.
	£		£		£		£		£	
Sundry doubtful..	..	..	..	..	118,851	459·859	..	..	139,600	540·141
Ireland	66	·636	6,038	58·186	11,086	106·831	20,326	195·872	8,202	79·039
Scotland	658,333	132·038	500,000	100·282	525,000	105·296	559,650	112·246	367,500	73·707
Isle of Man ..	817	339·286	259	107·558	191	79·319	..	..	60	24·917
North Wales ..	22,425	142·998	14,275	91·028	9,986	63·678	9,836	62·722	29,475	187·955
South Wales ..	172,287	116·151	149,279	100·639	167,493	112·919	185,361	124·965	128,590	86·691
Monmouthshire ..	..	..	..	..	..	..	..	..	38	·106
Durham and Northumberld.	3,000	9·215	3,430	10·536	37,500	115·187	52,650	161·722	30,000	92·150
Yorks W. Riding	58,875	54·123	87,625	80·552	118,750	109·164	113,750	104·568	143,750	132·146
Yorks N. Riding	169,369	25·874	253,413	38·714	623,642	95·275	698,243	106·673	763,856	116·697
Cumberland ..	259,680	48·299	306,591	57·025	414,529	77·102	529,690	98·521	512,176	95·264
Lancashire ..	259,590	71·619	279,695	77·166	329,321	90·858	345,710	95·375	303,720	83·794
Derbyshire ..	99,130	106·997	86,362	93·216	87,625	94·579	81,400	87·860	87,500	94·444
S. Staffordshire ..	227,342	120·245	253,931	134·308	297,500	157·352	280,450	148·334	189,606	100·285
N. Staffordshire ..	174,712	73·664	226,117	95·338	245,671	103·582	174,478	73·566	277,043	116·810
Warwickshire ..	4,000	97·475	3,687	89·848	3,150	76·762	3,938	95·965	4,125	100·522
Shropshire.. ..	48,403	69·936	48,837	70·563	61,800	89·293	63,209	91·328	68,453	98·906
Lincolnshire ..	13,404	35·966	20,825	55·879	27,847	74·720	17,890	48·003	29,678	79·633
Northamptonshire	28,535	30·234	31,940	33·842	41,644	44·123	84,761	89·808	96,137	101·861
Oxfordshire ..	2,100	97·295	1,235	57·218	1,921	89·001	2,666	123·517	881	40·817
Hampshire ..	1,707	213·910	1,549	194·110	665	83·334	2,335	292·606	1,724	216·040
Wiltshire	26,494	87·795	22,752	75·394	29,045	96·248	31,967	105·931	30,916	102·448
Herefordshire ..	..	..	..	..	..	..	..	..	93	632·653
Gloucestershire ..	45,189	65·700	73,807	107·308	57,373	83·415	63,830	92·803	68,983	100·294
Somersetshire ..	16,382	104·047	15,183	96·431	17,354	110·220	26,869	170·652	18,992	120·623
Devonshire ..	2,159	43·726	2,040	41·316	1,841	37·286	5,271	106·752	13,096	265·230
Cornwall	8,372	119·435	10,869	155·057	11,105	158·423	12,864	183·517	10,610	151·362
Total	2,302,371	70·099	2,399,739	73·064	3,240,890	98·674	3,367,144	102·518	3,324,804	101·229

District.	1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.
	£		£		£		£		£		£		£	
Sundry doubtful..	..	..	..	..	..	..	..	..	..	..	258,451	..	25,845	·787
Ireland	5,314	51·209	10,642	102·552	10,492	101·106	12,201	117·572	19,405	186·997	103,772	..	10,377	·316
Scotland	396,750	79·574	311,200	62·416	305,000	61·172	487,500	97·775	875,000	175·494	4,985,933	..	498,593	15·180
Isle of Man ..	..	..	..	..	67	27·824	1,014	421·096	..	..	2,408	..	241	·008
North Wales ..	17,005	108·436	12,123	77·305	10,536	67·185	10,429	66·503	20,730	132·190	156,820	..	15,682	·478
South Wales ..	130,041	87·670	131,231	88·472	105,398	71·056	180,607	121·760	133,019	89·677	1,483,306	..	148,331	4·516
Monmouthshire ..	15	·042	86,040	239·604	87,500	243·669	122,500	341·137	63,000	175·442	359,093	..	35,909	1·094
Durham and Northumberld.	27,250	83·702	31,770	97·586	31,250	95·989	39,875	122·482	68,833	211·431	325,558	..	32,556	·991
Yorks W. Riding	89,250	82·045	144,750	133·065	196,407	180·552	57,726	53·066	76,929	70·719	1,087,812	..	108,781	3·312
Yorks N. Riding	741,198	113·236	798,056	121·922	701,833	107·221	773,669	118·196	1,022,375	156·192	6,545,654	..	654,565	19·925
Cumberland ..	538,153	100·095	569,362	105·900	610,370	113·528	733,459	136·422	902,396	167·844	5,376,406	..	537,641	16·369
Lancashire ..	342,863	94·593	333,678	92·059	383,812	105·891	392,253	108·220	653,953	180·421	3,624,595	..	362,460	11·036
Derbyshire ..	82,375	88·913	87,500	94·444	91,860	99·150	88,018	95·003	134,703	145·394	926,473	..	92,647	2·821
S. Staffordshire ..	164,727	87·125	136,450	72·170	86,908	45·967	96,250	50·908	157,500	83·304	1,890,664	..	189,066	5·757
N. Staffordshire ..	206,530	87·080	212,237	89·486	214,466	90·426	321,937	135·739	318,547	134·309	2,371,738	..	237,174	7·221
Warwickshire ..	4,687	114·217	3,875	94·429	3,699	90·140	3,750	91·383	6,125	149·259	41,036	..	4,104	·125
Shropshire.. ..	71,477	103·275	62,500	90·304	69,635	100·614	79,621	115·042	118,169	170·739	692,104	..	69,210	2·107
Lincolnshire ..	41,733	111·979	48,053	128·937	51,425	137·985	62,850	168·641	58,980	158·257	372,685	..	37,268	1·135
Northamptonshire	118,941	126·023	104,191	110·395	222,279	118·964	135,065	143·107	190,312	201·643	943,805	..	94,381	2·874
Oxfordshire ..	543	25·158	..	..	..	..	2,537	117·541	9,701	449·453	21,584	..	2,158	·066
Hampshire ..	..	..	..	..	..	..	..	..	..	..	7,980	..	798	·024
Wiltshire	30,258	100·267	33,034	109·466	30,033	99·522	41,918	138·906	25,356	84·023	301,773	..	30,177	·919
Herefordshire ..	54	367·347	..	..	..	..	..	..	..	..	147	..	15	·001
Gloucestershire ..	72,982	106·109	70,271	102·167	75,334	109·528	77,460	112·619	82,576	120·057	687,805	..	68,780	2·094
Somersetshire ..	17,661	112·170	17,952	114·018	12,168	77·282	7,980	50·683	6,908	43·874	157,449	..	15,745	·479
Devonshire ..	12,504	253·240	3,179	64·383	3,668	74·287	2,131	43·159	3,487	70·621	49,376	..	4,938	·151
Cornwall	6,787	96·823	2,004	28·589	2,460	35·094	1,810	25·821	3,216	45·879	70,097	..	7,010	·214
Total	3,119,098	94·966	3,210,098	97·736	3,196,600	97·325	3,732,560	113·643	4,951,220	150·747	32,844,524	..	3,284,452	100·

TABLE III.—Continued.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

TIN ORE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	709,027	84·083	823,555	98·258	944,631	85·591	905,280	112·023	851,296	107·357	721,741	100·955	689,502	81·768	766,498	90·898	1,016,963	120·601	998,963	118·466	8,432,456	..	843,246	98·586
Devonshire ..	16,533	136·725	14,827	122·617	19,354	84·393	20,639	160·054	16,139	171·094	10,205	133·466	5,232	43·265	3,707	30·656	10,842	89·662	3,394	28·068	120,922	..	12,092	1·414
Total	725,560	84·827	843,382	98·602	963,985	85·574	925,969	112·702	867,435	108·257	731,946	101·414	694,734	81·223	770,205	90·047	1,027,805	120·166	1,002,357	117·188	8,553,378	..	855,338	100·

ZINC ORE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	℘ Cent	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.	Value.	℘ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	11,531	293·499	2,014	51·263	3,119	79·388	2,153	54·801	2,787	70·938	3,296	83·893	4,218	107·361	5,497	139·915	2,149	54·699	2,524	64·243	39,238	..	3,929	10·132
Devonshire ..	110	44·588	42	17·025	219	88·772	133	53·912	92	37·292	236	95·663	242	98·095	172	69·720	251	101·743	970	393·190	2,467	..	247	·636
Cumberland ..	1,118	75·531	953	64·383	1,280	86·475	1,592	107·553	1,818	122·821	1,286	86·880	1,664	112·417	1,337	90·326	2,015	136·130	1,739	117·484	14,802	..	1,480	3·817
Derbyshire ..	1,838	157·660	2,750	235·890	1,875	160·834	2,392	205·181	1,500	128·667	750	64·334	102	8·749	129	11·065	125	10·722	197	16·898	11,658	..	1,166	3·006
Shropshire.. ..	..	..	..	..	525	98·296	417	78·076	563	105·411	407	76·203	1,274	238·532	644	120·577	236	44·186	1,275	238·719	5,341	..	534	1·377
Staffordshire ..	..	..	..	..	..	..	..	..	125	51·954	547	227·348	238	98·919	122	50·707	1,112	462·178	262	108·894	2,406	..	241	·620
Anglesea	..	..	..	..	551	1000·	..	..	..	..	..	..	..	..	..	..	..	..	..	..	551	..	55	·142
Carnarvon.. ..	..	..	252	475·472	2	3·773	45	84·906	..	..	..	..	..	..	18	33·962	..	..	213	401·887	530	..	53	·137
Denbighshire ..	1,875	23·413	1,801	22·489	2,949	36·824	8,820	110·134	12,118	151·316	12,312	153·738	9,525	118·938	12,258	153·064	9,357	116·840	9,069	113·244	80,084	..	8,008	20·652
Flintshire	2,343	63·992	1,810	49·435	1,150	31·409	1,092	29·825	1,412	38·564	1,681	45·911	5,200	142·022	7,755	211·804	7,409	202·354	6,762	184·684	36,614	..	3,661	9·442
Montgomeryshire	..	..	..	..	..	..	..	..	247	61·904	57	14·285	593	148·621	422	105·767	293	73·433	2,378	595·990	3,990	..	399	1·029
Merionethshire ..	..	..	..	..	..	..	..	..	237	1000·	..	..	..	..	..	..	..	..	..	..	237	..	24	·061
Brecknockshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	165	1000·	165	..	16	·043
Cardiganshire ..	4,415	467·889	624	66·129	2,251 } Omittd inTotal	..	499	52·883	2,299	243·641	232	24·587	483	51·187	177	18·758	176	18·652	531	56·274	9,436	..	944	2·433
Caermarthenshire	..	..	230	23·053	2,527	253·283	3,773	378·170	2,065	206·976	1,180	118·272	..	..	..	..	..	..	202	20·246	9,977	..	998	2·573
Pembrokeshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	154	1000·	..	..	..	..	154	..	15	·040
Isle of Man ..	6,103	45·961	1,382	10·408	5,555	41·834	14,431	108·678	18,938	142·619	18,897	142·310	17,372	130·826	10,260	77·267	26,015	195·915	13,834	104·182	132,787	..	13,279	34·243
Ireland— Tipperary ..	1,780	48·500	4,192	114·220	10,216	278·358	9,215	251·083	8,140	221·792	1,354	36·893	429	11·689	246	6·703	192	5·231	937	25·531	36,701	..	3,670	9·464
Scotland	..	..	..	..	..	..	..	..	137	231·029	420	708·263	..	..	..	..	36	60·708	..	..	593	..	59	·153
Total	31,113	80·233	16,050	41·389	29,968	77·281	44,562	114·915	52,478	135·329	42,655	109·998	41,340	106·607	39,191	101·065	49,366	127·304	41,058	105·879	387,781		38,778	100·

TABLE III.—CONTINUED.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

COPPER ORE.

District.	1861.		1862.		1863.		1864.		1865.	
	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.
	£		£		£		£		£	
Cornwall	805,491	155·326	728,299	140·440	642,944	123·981	659,919	127·254	572,618	110·420
Devonshire	215,961	136·622	201,041	127·183	189,209	119·698	194,198	122·854	184,777	116·894
Cumberland ...	975	255·838	305	80·031	...	...	...	...	174	45·657
Lancashire	17,104	144·641	19,050	161·098	15,266	129·098	13,808	116·769	12,176	102·968
Yorkshire	...	...	...	...	...	...	513	418·093	400	325·998
Cheshire	18,412	114·968	15,885	99·189	15,000	93·663	15,000	93·663	14,904	93·063
Shropshire	...	...	...	...	...	...	...	...	...	...
Staffordshire ...	...	...	...	...	...	...	126	344·262	...	...
Cardiganshire ...	643	47·472	2,615	193·060	...	...	2,851	210·484	2,593	191·436
Carnarvonshire ...	4,689	171·833	4,835	177·184	2,971	108·876	...	...	4,371	160·180
Flintshire	...	...	...	...	263	970·480	...	...	...	...
Montgomeryshire...	703	183·791	...	...	...	...	551	144·052	...	...
Anglesea	16,798	56·853	31,548	106·774	28,480	96·391	26,160	88·539	38,925	131·741
Isle of Man... ...	8,783	240·498	5,001	136·939	5,963	163·280	571	15·635	8,025	219·743
Scotland (Renfrew)	1,752	653·731	858	320·149	...	...	...	...	70	26·120
Cork	70,037	142·729	74,269	151·353	76,080	155·044	70,411	143·491	48,249	98·327
Waterford	61,438	150·195	46,578	113·868	47,438	115·970	47,415	115·913	30,827	75·361
Wicklow	1,968	41·541	1,684	35·546	2,565	54·142	4,345	91·715	6,590	139·103
Kerry	1,563	342·013	3,007	657·987	...	...	...	...	...	...
Sundries undivided	200,898	398·670	81,800	162·327	74,375	147·593	119,603	237·345	3,239	6·428
Total	1,427,215	160·602	1,216,775	136·922	1,100,554	123·844	1,155,471	130·024	927,938	104·420

District.	1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.	Value.	Per Cent.
	£		£		£		£		£		£		£	
Cornwall	431,083	83·127	413,876	79·809	373,006	71·928	316,364	61·006	242,227	46·709	5,185,827	...	518,583	58·355
Devonshire	151,481	95·831	144,774	91·588	128,748	81·449	86,433	54·680	84,095	53·201	1,580,717	...	158,072	17·788
Cumberland ...	205	53·792	386	101·286	599	157·177	578	151·666	589	154·553	3,811	...	381	·043
Lancashire	11,120	94·037	10,486	88·676	7,006	59·247	6,650	56·236	5,585	47·230	118,251	...	11,825	1·331
Yorkshire	...	...	...	...	...	...	...	...	314	255·909	1,227	...	123	·014
Cheshire	15,275	95·380	16,500	103·029	11,750	73·369	10,592	66·138	26,831	167·538	160,149	...	16,015	1·802
Shropshire	205	191·948	766	717·228	97	90·824	...	...	...	...	1,068	...	107	·012
Staffordshire ...	...	...	72	196·721	152	415·301	...	...	16	43·716	366	...	36	·004
Cardiganshire ...	1,340	98·929	1,050	77·519	650	47·988	989	73·016	814	60·096	13,545	...	1,354	·153
Carnarvonshire ...	1,400	51·305	4,898	179·493	775	28·401	1,664	60·979	1,685	61·749	27,288	...	2,729	·307
Flintshire	8	29·520	...	...	...	...	...	...	...	...	271	...	27	·003
Montgomeryshire...	...	...	...	...	1,529	399·739	594	155·294	448	117·124	3,825	...	382	·043
Anglesea	48,690	164·791	20,706	70·079	34,937	118·244	21,059	71·274	28,162	95·314	295,465	...	29,547	3·325
Isle of Man... ...	900	24·644	1,400	38·335	2,071	56·709	2,152	58·927	1,654	45·290	36,520	...	3,652	·411
Scotland (Renfrew)	...	...	...	...	...	...	...	...	...	...	2,680	...	268	·030
Cork	39,240	79·967	42,320	86·244	29,624	60·371	29,538	60·196	10,932	22·278	490,700	...	49,070	5·522
Waterford	49,120	120·082	38,478	94·066	47,898	117·094	29,929	73·166	9,934	24·285	409,055	...	40,905	4·603
Wicklow	6,535	137·942	1,580	33·351	356	7·515	6,776	143·029	14,976	316·116	47,375	...	4,738	·533
Kerry	...	...	...	...	...	...	...	...	...	...	4,570	...	457	·051
Sundries undivided	2,516	4 993	2,401	4·764	2,905	5·765	6,594	13·086	9,589	19·029	503,920	...	50,392	5·670
Total	759,118	85·422	699,693	78·735	642,103	72·255	519,912	58·505	437,851	49·271	8,886,630	...	888,663	100·

TABLE III.—CONTINUED.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

LEAD ORE.

District.	1861.		1862.		1863.		1864.		1865.	
	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.
	£		£		£		£		£	
Cornwall	83,849	92·193	75,376	82·877	81,846	89·991	75,774	83·314	83,453	91·758
Devonshire ..	34,624	178·093	25,988	133·673	20,638	106·155	23,667	121·734	23,560	121·181
Somersetshire ..	10,777	71·396	9,375	62·108	9,152	60·632	33,929	224·774	13,386	88·680
Derbyshire ..	92,444	115·693	88,101	110·258	80,804	101·126	85,836	107·423	80,100	100·245
Staffordshire ..	501	19·256	750	28·827	..	..	7,174	275·732	3,774	145·054
Shropshire.. ..	57,849	101·029	51,976	90·773	55,031	96·108	54,437	95·071	47,374	82·736
Cheshire	1,339	1000·	..	..	..	..	..	..	..	..
Lancashire ..	..	..	..	..	..	..	..	..	..	..
Yorkshire	110,301	103·971	115,689	109·050	117,435	110·696	124,037	116·919	97,120	91·547
Cumberland ..	79,258	107·803	89,676	121·973	87,484	118·992	91,595	124·584	78,698	107·042
Westmoreland ..	29,986	106·923	25,225	89·948	30,267	107·927	29,398	104·828	23,980	85·509
Durham and Northumbrld.	244,840	86·206	272,153	95·822	297,770	104·841	329,137	115·886	274,123	96·516
Carnarvon.. ..	2,165	74·555	2,950	101·588	4,027	138·676	2,715	93·495	3,022	104·067
Denbighshire ..	95,832	95·781	99.063	99·010	103,545	103·489	138,544	138·470	95,717	95·665
Flintshire	55,279	89·110	65,151	105·023	60,772	97·964	77,461	124·867	78,239	126·122
Montgomery ..	30,736	61·145	53,613	106·654	47,716	94·923	44,333	88·193	38,552	76·693
Merionethshire ..	2,594	327·940	2,463	311·378	379	47·914	243	30·721	38	4·804
Cardiganshire ..	97,190	99·865	103,738	106·593	93,249	95·815	106,673	109·609	99,886	102·635
Caermarthenshire	18,071	156·924	16,225	140·894	13,075	113·540	13,877	120·504	11,844	102·850
Pembrokeshire ..	1,215	32·473	4,237	113·240	3,268	87·342	5,016	134·060	4,105	109·712
Brecknockshire ..	..	..	25	52·083	..	..	100	208·333	153	318·750
Radnorshire ..	463	1000·	..	..	..	..	..	..	..	..
Isle of Man ..	34,062	78·110	31,363	71·912	33,492	76·794	44,562	102·177	40,069	91,875
Ireland	30,115	113·469	33,050	124·527	31,543	118·849	31,470	118·574	22,667 }	97·222
Do. Silver Ores..	..	..	..	..	..	..	..	..	3,136 }	
Scotland	22,070	73·573	22,088	73·633	19·030	63·438	29,627	98·765	30,138	100·468
Sundries under 10 tons ..	689	101·012	3,125	458·144	3,007	440·844	..	..	..	..
Total	1,136,249	95·618	1,191,400	100·259	1,193,530	100·438	1,349,605	113·572	1,153,134	97·039

District.	1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.	Value.	℔ Cent.
	£		£		£		£		£		£		£	
Cornwall	85,912	94·462	107,153	117·816	101,690	111·809	110,759	121·781	103,681	113·999	909,493	..	90,949	7·654
Devonshire ..	9,221	47·431	9,953	51·195	18,398	94·663	13,268	68·246	15,098	77·659	194,415	..	19,441	1·636
Somersetshire ..	14,438	95·648	10,957	72·588	13,715	90·860	18,873	125·031	16,345	108·283	150,947	..	15,095	1·270
Derbyshire ..	82,022	102·650	60,945	76·272	71,690	89·720	79,449	99·430	77,654	97·183	799,045	..	79,904	6·724
Staffordshire ..	2,576	99·008	1,029	39·549	1,398	53·732	6,457	248·174	2,359	90·668	26,018	..	2,602	·219
Shropshire.. ..	51,501	89·943	55,851	97·539	59,727	104·309	68,813	120·177	70,038	122·315	572,597	..	57,260	4·819
Cheshire	..	..	..	..	..	..	..	..	..	..	1,339	..	134	·011
Lancashire ..	3,189	186·830	8,552	501·025	5,328	312·145	..	..	..	..	17,069	..	1,707	·144
Yorkshire	124,162	117·036	93,444	88·081	92,967	87·632	105,114	99·082	80,612	75·986	1,060,881	..	106,088	8·928
Cumberland ..	71,691	97·511	70,439	95·809	66,703	90·727	54,566	74·218	45,098	61·341	735,208	..	73,521	6·187
Westmoreland ..	24,743	88·229	29,971	106·869	24,814	88·482	30,920	110·255	31,137	111·030	280,441	..	28,044	2·360
Durham and Northumbrld.	287,670	101·205	279,799	98·514	286,628	100·918	255,235	89·865	312,839	110·147	2,840,194	..	284,019	23·901
Carnarvon.. ..	3,329	114·639	3,756	129·343	2,881	99·211	1,981	68·219	2,213	76·207	29,039	..	2,904	·244
Denbighshire ..	82,571	82·526	111,392	111·332	99,881	99·827	89,115	89·067	84,879	84·833	1,000,539	..	100,054	8·420
Flintshire	67,533	108·864	52,083	83·957	52,218	84·176	58,297	93·975	53,313	85·942	620,346	..	62,035	5·220
Montgomery ..	39,219	78·020	44,472	88·471	48,567	96·616	67,768	134·814	87,703	174·471	502,679	..	50,268	4·230
Merionethshire ..	191	24·146	310	39·191	677	85·588	..	..	1,015	128·318	7,910	..	791	·067
Cardiganshire ..	98,207	100·910	97,162	99·836	87,371	89·775	100,412	103·175	89,329	91·787	973,217	..	97,322	8·190
Caermarthenshire	10,267	89·156	10,189	88·479	6,042	52·467	7,438	64·590	8,130	70·596	115,158	..	11,516	·969
Pembrokeshire ..	3,928	104·982	3,495	93·410	3,552	94·933	4,419	118·105	4,181	111·743	37,416	..	3,742	·315
Brecknockshire ..	128	266·667	74	154·167	..	..	..	..	..	..	480	..	48	·004
Radnorshire ..	..	..	..	..	..	..	..	..	..	..	463	..	46	·004
Isle of Man ..	44,563	102·179	47,087	107·968	51,837	118·858	52,807	121·082	56,284	129·055	436,126	..	43,613	3·670
Ireland	23,251	87·606	23,339	87·939	52,242	95·108	24,292	91·529	17,298	65·177	265,403	..	26,540	2·233
Do. Silver Ores..														
Scotland	30,916	103·062	36,614	122·057	29,442	98·148	39,047	130·168	41,003	136·688	299,975	..	29,997	2·524
Sundries under 10 tons ..	..	..	..	..	..	..	..	..	..	..	6,821	..	682	·057
Total	1,161,228	97·720	1,158,066	97·454	1,150,768	96·840	1,189,030	100·060	1,200,209	101·000	11,883,219	..	1,188,322	100·

TABLE III.—Continued.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

IRON PYRITES.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of Ten Years.		Average.	
	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	17,661	205·063	12,868	149·411	6,920	80·348	7,434	86·316	8,609	99·959	9,635	111·872	8,847	102·723	7,058	81·951	2,664	30·932	4,429	51·425	86,125	..	8,613	14·228
Devonshire ..	1,156	95·616	892	73·780	265	21·919	755	62·449	1,347	111·414	729	60·298	518	42·845	496	41·026	3,803	314·557	2,129	176·096	12,090	..	1,209	1·997
Cumberland ..	3,468	476·047	1,712	235·003	1,875	257·378	230	31·572	..	..	..	..	..	..	..	..	..	..	..	..	7,285	..	729	1·204
Durham and Northumberld	1,300	31·542	1,700	41·248	10,398	252·293	7,000	169·845	6,090	147·766	4,750	115·252	1,875	45·494	1,320	32·028	4,281	103·873	2,500	60·659	41,214	..	4,121	6·809
Yorkshire	1,200	44·991	1,275	47·803	4,056	152·070	3,079	115·440	7,699	288·655	1,625	60·925	1,700	63·737	1,450	54·364	1,475	55·301	3,113	116·714	26,672	..	2,667	4·406
Lancashire ..	1,450	121·767	1,320	110·850	1,275	107·071	1,013	85·069	1,100	92·375	1,250	104·972	1,250	104·971	1,000	83·977	1,125	94·474	1,125	94·474	11,908	..	1,191	1·967
Shropshire.. ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	32	1000·	32	..	3	·005
Anglesea	..	..	..	..	215	206·137	237	227·229	241	231·064	73	69·990	100	95·877	87	83·413	..	..	90	86·290	1,043	..	104	·172
Carnarvon ..	312	73·898	391	92·610	404	95·689	353	83·610	317	75·083	407	96·400	427	101·137	551	130·507	525	124·349	535	126·717	4,222	..	422	·698
Montgomeryshire	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	824	1000·	824	..	82	·136
Denbighshire Flintshire	400	103·172	500	128·965	750	193·449	675	174·104	675	174·104	427	110·137	450	116·069	..	..	..	..	..	..	3,877	..	388	·641
Ireland (Wicklow)	52,768	128·699	37,555	91·595	35,877	87·503	37,321	91·024	45,096	109·987	59,036	143·986	52,286	127·523	41,674	101·641	27,150	66·217	21,249	51·825	410,012	..	41,001	67·737
Total	79,715	131·694	58,213	96·172	62,035	102·486	58,097	95·980	71,174	117·584	77,932	128·748	67,453	111·437	53,636	88·610	41,023	67·772	36,026	59·517	605,304	..	60,530	100·

MANGANESE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of Ten Years.		Average.	
	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.	Value.	₰ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall and Devonshire	2,925	71·253	..	..	..	..	..	..	..	..	..	..	3,080	75·029	7,650	186·353	7,897	192·371	19,499	474·994	13,655 27,396	..	1,365 2,740	..
Carnarvonshire ..	..	..	..	..	..	..	..	..	..	..	..	..	20	1000·	..	..	..	..	..	..	20	..	2	..
Merionethshire ..	..	..	..	..	..	..	..	..	..	..	..	..	132	1000·	..	..	..	..	..	..	132	..	13	..
Total	2,925	70·990	..	..	..	..	..	..	..	..	..	..	3,232	78·441	7,650	185·666	7,897	191·661	19,499	473·242	41,203	..	4,120	..

TABLE III.—Continued.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON THE TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

ARSENIC.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall... ...	...	...	820	...	...	...	...	...	604	...	1,301	...	2,074	...	3,608	...	3,738	...	5,182	...	17,327	...	1,733	...
	10,875	...	...	...	1,200	...	1,393	...	...	...	...	...	...	...	...	...	...	...	...	...	13,468	...	1,347	...
Devonshire ...	...	...	...	...	...	...	...	...	...	...	...	...	38	...	2,802	...	7,726	...	12,557	...	23,123	...	2,312	...
Prod. at Swansea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3,300	...	...	...	...	...	3,300	...	330	...
Estimated ...	...	...	...	...	...	...	...	...	...	...	...	...	2,000	...	...	...	...	...	...	...	2,000	...	200	...
Total	10,875	183·644	820	13·847	1,200	20·261	1,393	23·523	604	10·200	1,301	21·970	4,112	69·438	9,710	163·970	11,464	193·590	17,739	299·554	59,218	...	5,922	...

GOSSANS, OCHRES, UMBERS, &c.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	3,016	...	5,000	...	2,261	...	649	...	839	...	1,365	...	943	...	1,297	...	257	...	142	...	15,769	...	1,577	...
															1,000	...	...	...	...	...	1,000	...	100	...
Devonshire ...	...	...	...	...	100	...	65	...	...	...	49	...	57	...	63	...	127	...	34	...	495	...	49	...
Isle of Man ...	444	...	...	...	...	...	...	...	...	...	75	...	...	...	522	...	559	...	35	...	1,935	...	194	...
Anglesea	...	...	...	...	2,215	...	2,045	...	...	...	1,560	...	4,808	...	3,490	...	...	...	...	...	14,118	...	1,412	...
Pt. Cornwall ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4,000	...	3,750	...	7,750	...	775	...
Pt. Devonshire ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Total	3,460	84·253	5,000	121·752	4,576	111·428	2,759	67·183	839	20·430	3,049	74,245	5,808	141·427	6,372	1 551 61	4,943	120·364	4,261	103·757	41,067	...	4,107	...

COPROLITES.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.	Value.	⅌ Cent.
	£		£		£		£		£		£		£		£		£		£		£		£	
Bedfordshire ...	...	...	...	...	...	...	...	...	...	...	...	...	13,300	...	14,300	...	...	...	...	...	27,600	...	2,760	...
Cambridgeshire	...	...	...	...	...	...	...	...	...	...	...	...	57,000	...	57,200	...	...	...	...	...	114,200	...	11,420	...
Hertfordshire ...	75,000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75,000	...	7,500	...
Suffolk	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Estimated ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	50,000	...	50,000	...	5,000	...
Total	75,000	281·110	...	...	...	...	...	...	...	...	...	...	70,300	263·493	71,500	267·991	...	...	50,000	187·406	266,800	...	26,680	...

TABLE III.—CONTINUED.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF THE SAME DISTRICT FOR TEN YEARS.

BARYTES.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Northumberland...	...	...	...	...	...	...	...	...	...	...	...	...	3,449	451·086	959	125·425	1,540	201·412	1,698	222·077	7,646	...	765	16·421
Durham	...	...	...	...	...	...	...	...	3,025	1000·	...	...	...	...	...	...	...	...	...	...	3,025	...	303	6·497
Cumberland (Alston Moor)	41	34·253	11	9·190	...	...	13	10·861	50	41·771	124	103·592	385	321·637	131	109·440	100	83·542	342	285·714	1,197	...	119	2·571
Yorkshire	584	614·090	367	385·910	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	951	...	95	2·043
Derbyshire ...	5,508	245·674	4,718	210·437	...	...	...	...	...	...	...	...	3,053	136·173	6,242	278·412	1,469	65·521	1,430	63·783	22,420	...	2,242	48·151
Shropshire ...	62	8·404	549	74·411	...	...	354	47·980	1,920	260·233	1,627	220·520	920	124·695	1,396	189·211	249	33·749	301	40·797	7,378	...	738	15·845
North Wales ...	1,245	640·762	698	359·238	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,943	...	194	4·173
Montgomeryshire	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	57	1000.	...	...	57	...	6	·122
Scotland (Kirkcudbright)	128	537·815	110	462·185	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	238	...	24	·511
Isle of Arran ...	459	461·307	536	538·693	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	995	...	99	2·137
Ireland	382	536·517	330	463·483	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	712	...	71	1·529
Total	8,409	180·598	7,319	157·188	...	...	367	7·882	4,995	107·276	1,751	37·606	7,807	167·669	8,728	187·449	3,415	73,343	3,771	80·989	46,562	...	4,656	100·

CLAYS (FINE AND FIRE).

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Cent.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	70,288	66·185	72,057	67·850	72,005	67·801	104,978	98·849	110,579	104·123	125,009	117·710	143,709	135·318	115,420	108·681	120,205	113·187	127,755	120·296	1,062,005	...	106.201	28·608
Devonshire ...	17,415	68·589	15,352	60·463	17,082	67·277	25,712	101·266	25,712	101·266	29,941	117·921	31,633	124·585	29,850	117·563	29,385	115·732	31,824	125·338	253,906	...	25,391	6·840
Dorsetshire ...	56,678	130·280	60,390	138·813	51,355	118·045	50,125	115·217	50,125	115,217	50,125	115·217	37,500	86·197	3,750	8·620	37,500	86·197	37,500	86·197	435,048	...	43,505	11·719
Staffordshire ...	48,795	}																						
Yorkshire ...	31,250	}																						
Derbyshire ...	...	} 49·334	125,000	70·542	125,000	70·542	187,500	105·813	187,500	105·812	187,500	105·812	187,500	105·813	168,750	95·231	262,910	148·369	252,921	142·732	1,772,001	...	177,200	47,733
Do., adjacent Counties ...	7,375	}																						
Sundry	...	...	...	...	...	...	...	...	...	...	...	...	189,308	1000·	...	...	...	...	...	...	189,308	..	18,931	5·100
Total	231,801	62·442	272,799	73·486	265.442	71,504	368,315	99·216	373,916	100·725	392,575	105·751	589,650	158·838	317,770	85·600	450,000	121·219	450,000	121·219	3,712,268	...	371,228	100.

TABLE III.—CONTINUED.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF SAME DISTRICT FOR TEN YEARS.

SALT.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 4 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cheshire	..	..	..	..	..	..	..	..	..	..	..	..	750,000	100·649	765,625	112·955	570,640	84·188	625,000	92·208	2,711,265	..	271,126	84·822
Worcestershire	..	..	..	..	..	..	..	..	..	..	..	..	75,150	68·411	147,000	133·819	107,250	97·633	110,000	100·137	439,400	..	43,940	13·747
Ireland	..	..	..	..	..	..	..	..	..	..	..	..	11,813	103·283	14,602	127·667	9,610	84·023	9,725	85·027	45,750	..	4,575	1·431
Total	..	..	..	..	..	..	..	..	..	..	..	..	836,963	104·738	927,227	116·033	687,500	86·034	744,725	93·195	3,196,415	..	319,641	100·

SILVER ORE.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	1,471	..	15,095	..	5,703	..	38	..	..	..	..	..	..	..	..	..	..	..	..	..	22,307	..	2,231	..

ANTIMONY.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	45	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	45	..	5	..

FLUOR SPAR.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	..	..	..	..	..	..	13	..	46	..	2	..	..	..	42	..	..	..	..	..	103	..	10	..

NICKEL ORE.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
	£		£		£		£		£		£		£		£		£		£		£		£	
Cornwall	24	..	..	..	..	..	..	..	..	..	..	..	14	..	..	..	..	..	..	..	38	..	4	..
Linlithgow	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	27	..	27	..	3	..
Total	24	..	..	..	..	..	..	..	..	..	..	..	14	..	..	..	..	..	27	..	65	..	7	..

TABLE III.—Continued.

ANNUAL PER CENTAGE VALUE OF EACH DISTRICT ON TOTAL VALUE OF SAME DISTRICT FOR TEN YEARS.

OXIDE OF IRON.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
Cornwall	..	..	..	..	..	..	5	..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..

TUNGSTATE OF SODA.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
Cornwall	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	212	..	379	..	591	..	59	..

URANIUM.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
Cornwall	..	..	..	..	23	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	23	..	2	..

WOLFRAM.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
Cornwall	29	..	63	..	67	..	14	..	11	..	..	..	62	..	67	..	111	..	274	..	698	..	70	..

GOLD QUARTZ.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
Merionethshire	10,000	..	15,000	..	1,500	..	642	..	..	..	..	..	5,320	..	1,000	..	..	..	..	..	33,462	..	3,346	..
Sutherlandshire	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

EARTHY MINERALS.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.		Average.	
	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.	Value.	Per Ct.
.. .. ..	554,460	..	1,469,882	..	1,709,558	..	1,131,685	..	1,044,085	..	1,126,322	..	650,000	..	650,000	..	670,000	..	575,000	..	9,580,992	..	958,099	..

TABLE IV.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

COAL.

District.	1861. Tons.	1861. Per Ton.	1862. Tons.	1862. Per Ton.	1863. Tons.	1863. Per Ton.	1864. Tons.	1864. Per Ton.	1865. Tons.	1865. Per Ton.	1866. Tons.	1866. Per Ton.	1867. Tons.	1867. Per Ton.	1868. Tons.	1868. Per Ton.	1869. Tons.	1869. Per Ton.	1870. Tons.	1870. Per Ton.	Total of 10 Years. Tons.	Ave age. Tons.	Ave age. Per Ton.
Durham and Northumberland	19,144,965	..	19,360,856	..	22,154,146	..	23,284,367	..	25,032,694	..	25,194,550	..	24,867,444	..	24,394,167	..	25,765,430	..	27,613,539	..	236,811,658	23,681,166	s. d. 4 11·741
Cumberland ..	1,255,644	..	1,330,287	..	1,327,868	..	1,380,795	..	1,431,047	..	1,490,481	..	1,512,514	..	1,378,026	..	1,410,808	..	1,408,235	..	13,925,205	1,392,521	4 11·735
Yorkshire	9,374,600	..	9,255,500	..	9,402,500	..	8,809,600	..	9,355,100	..	9,714,700	..	9,843,575	..	9,740,510	..	10,829,827	..	10,606,604	..	96,932,516	9,693,252	4 11·730
Derbyshire	..	..	4,534,800	..	4,550,750	..	4,470,750	..	4,595,750	..	4,750,520	..	4,550,550	..	4,957,879	..	5,460,090	..	5,102,265	..	42,973,354	4,297,335	4 11·637
Derbyshire and Notts	5,116,319	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5,116,319	511,632	5 0
Notts ..	..	..	732,666	..	750,000	..	796,700	..	1,095,500	..	1,600,560	..	1,575,000	..	1,508,439	..	1,575,450	..	2,115,372	..	11,749,687	1,174,969	4 11·822
Leicestershire ..	740,000	..	696,024	..	805,750	..	890,500	..	965,500	..	866,560	..	1,150,000	..	608,088	..	650,700	..	599,450	..	7,972,572	797,257	4 11·719
Warwickshire ..	647,000	..	678,000	..	685,500	..	754,000	..	859,000	..	775,000	..	880,850	..	624,859	..	585,630	..	647,540	..	7,137,379	713,738	4 11·733
Staffordshire and Worcestershire	9,253,750	..	9,522,750	..	9,870,620	..	11,459,851	..	12,200,989	..	12,298,580	..	12,526,554	..	12,294,780	..	12,669,107	..	13,230,062	..	115,327,043	11,532,704	4 11·761
Lancashire ..	12,195,500	..	10,597,500	..	10,875,500	..	11,530,000	..	11,962,000	..	12,320,500	..	12,841,500	..	12,800,500	..	13,995,500	..	13,810,600	..	122,929,100	12,292,910	4 11·754
Cheshire	801,570	..	787,750	..	822,750	..	822,750	..	850,000	..	895,500	..	935,000	..	937,500	..	957,150	..	929,150	..	8,739,120	873,912	4 11·738
Shropshire ..	829,750	..	1,029,750	..	1,150,000	..	1,150,000	..	1,135,000	..	1,220,700	..	1,558,500	..	1,495,500	..	1,392,862	..	1,343,300	..	12,305,362	1,230,536	4 11·740
Gloucestershire Somersetshire	..	..	1,750,000	..	1,950,000	..	1,950,000	..	1,875,000	..	1,850,700	..	1,975,000	..	1,969,000	..	1,979,950	..	1,955,910	..	17,255,560	1,725,556	4 11·686
Gloucestershire, Somersetshire, Devonshire and Monmouthshire	6,511,025	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6,511,025	651,103	5
Devonshire Monmouthshire	..	..	3,750,000	..	4,075,000	..	4,028,500	..	4,125,000	..	4,445,000	..	4,569,500	..	4,250,500	..	4,275,150	..	4,364,342	..	37,882,992	3,788,299	4 11·564
South Wales ..	6,690,771	..	6,749,455	..	6,917,081	..	6,948,000	..	7,911,507	..	9,376,443	..	9,092,300	..	8,959,500	..	9,179,650	..	9,299,770	..	81,124,477	8,112,448	4 11·763
North Wales ..	1,870,250	..	1,660,000	..	1,728,000	..	1,987,060	..	1,983,000	..	2,082,000	..	2,371,250	..	2,385,000	..	2,155,180	..	2,329,030	..	20,550,770	2,055,077	4 11·766
Scotland	11,081,000	..	11,076,000	..	11,100,500	..	12,400,000	..	12,650,000	..	12,625,000	..	14,125,943	..	14,709,959	..	14,417,150	..	14,934,553	..	129,120,105	12,912,010	4 11·761
Ireland	123,070	..	127,500	..	127,050	..	125,000	..	123,500	..	123,750	..	125,000	..	126,950	..	127,923	..	141,470	..	1,271,213	127,121	4 11·722
Total ..	85,635,214	5s.	83,638,338	5s.	88,292,515	s. d. 4 9·218	92,787,873	5s.	98,150,587	5s.	101,630,544	5s.	104,500,480	5s.	103,141,157	5s.	107,427,557	5s.	110,431,192	5s.	975,635,457	97,563,546	4 11·748

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

IRON ORE.

DISTRICT.	1861. Tons.	1861. Per Ton. s. d.	1862. Tons.	1862. Per Ton. s. d.	1863. Tons.	1863. Per Ton. s. d.	1864. Tons.	1864. Per Ton. s. d.	1865. Tons.	1865. Per Ton. s. d.	1866. Tons.	1866. Per Ton. s. d.
Sundry doubtful	..	..	..	..	487,601	4 10½	..	..	86,420	..	..	..
Ireland	165	8 0	10,431	11 7	31,673	7 0	60,602	6 8¼	29,117	5 7½	25,525	4 2
Scotland	1,975,000	6 8	1,500,000	6 8	1,500,000	7 0	1,950,000	6 8	1,470,000	5 0	1,587,000	5 0
Isle of Man	967	16 10½	647	8 0	340	11 2½	..	..	120	10 0	..	..
North Wales	86,500	5 2½	54,156	5 3½	28,282	6 0	29,127	6 9	98,250	6 0	56,682	6 0
South Wales	545,706	6 3¾	472,053	6 4	420,017	8 0	468,355	7 11	387,742	6 7½	368,692	7 0½
Monmouthshire	..	..	..	..	..	..	..	..	150	5 0	60	5 0
Durham and Northd.	10,750	5 7	12,475	5 6	125,000	6 0	175,500	6 0	120,000	5 0	105,000	5 2½
Yorkshire, West Riding	235,500	5 0	350,500	5 0	475,000	5 0	555,000	4 1¼	575,000	5 0	357,000	5 0
Yorkshire, North Riding	1,130,761	3 0	1,690,097	3 0	2,078,806	6 0	2,401,891	5 9¾	2,755,939	5 6½	2,809,061	5 3½
Cumberland	472,195	11 0	533,940	11 6	690,975	12 0	863,667	12 3½	797,060	12 10	838,047	12 10
Lancashire	519,180	10 0	559,391	10 0	658,642	10 0	691,422	10 0	607,439	10 0	685,726	10 0
Derbyshire	396,520	5 0	345,450	5 0	350,500	5 0	325,600	5 0	350,000	5 0	329,500	5 0
South Staffordshire	727,500	6 3	700,500	7 3	850,000	7 0	948,500	5 11	659,500	5 9	599,000	5 6
North Staffordshire	499,195	7 0	646,334	7 0	681,809	7 2½	582,750	6 0	825,491	6 8½	612,243	6 9
Warwickshire	15,250	5 3	14,750	5 0	12,500	5 0½	15,750	5 0	16,500	5 0	18,750	5 0
Shropshire	223,400	4 4	225,400	4 4	247,200	5 0	254,590	4 11½	273,810	5 0	285,907	5 0
Lincolnshire	33,559	8 0	52,172	8 0	69,618	8 0	74,619	4 9½	124,959	4 9	175,720	4 9
Northamptonshire	113,139	5 0½	116,718	5 3¼	126,578	6 7	335,787	5 0½	384,349	5 0	476,981	5 0
Oxfordshire	5,600	7 6	2,244	11 0	4,803	8 0	6,666	8 0	2,557	6 10¾	1,552	7 0
Hampshire	4,008	8 6¼	3,476	8 11	1,400	9 6	5,100	9 1¼	3,525	9 9½	..	..
Wiltshire	55,779	9 6	47,901	9 6	72,612	8 0	79,918	8 0	77,291	8 0	75,645	8 0
Herefordshire	..	..	..	..	..	..	..	..	206	9 0	115	4 9½
Gloucestershire	100,420	9 0	164,015	9 0	127,497	9 0	141,843	9 0	152,710	9 0½	162,129	9 0
Somersetshire	32,763	10 0	31,413	9 8	34,709	10 0	52,925	10 2	37,984	10 0	35,323	10 0
Devonshire	5,399	8 0	3,550	11 6	7,014	5 3	11,068	9 6½	37,814	6 11	40,671	6 2
Cornwall	26,262	6 4¼	24,627	8 10	18,976	11 8½	34,210	7 6½	36,112	5 10½	18,683	7 3¼
Total	7,215,518	4·58	7,562,240	6 4·16	9,101,552	1·46	10,064,890	8·29	9,910,045	6 8·58	9,665,012	6 5·45

DISTRICT.	1867. Tons.	1867. Per Ton. s. d.	1868. Tons.	1868. Per Ton. s. d.	1869. Tons.	1869. Per Ton. s. d.	1870. Tons.	1870. Per Ton. s. d.	Total of 10 Years. Tons.	Average. Tons.	Average. Per Ton. s. d.
Sundry doubtful	..	..	..	..	..	..	..	..	574,021	57,402	9 0·06
Ireland	42,016	5 1	41,469	5 0¼	48,804	5 0	77,600	5 0	367,402	36,740	5 7·79
Scotland	1,264,800	4 11	1,250,000	4 10½	1,950,000	5 0	3,500,000	5 0	17,946,800	1,794,680	5 6·68
Isle of Man	..	..	220	6 0¾	1,292	15 8¾	..	..	3,586	359	13 5·16
North Wales	44,082	5 6	36,313	5 9¾	33,493	6 2¾	59,240	7 0	526,125	52,612	5 11·54
South Wales	501,186	5 3	362,680	5 1½	531,011	8 5¾	380,055	7 0	4,437,497	443,750	6 8·22
Monmouthshire	341,057	5 0½	350,000	5 1½	183,990	8 5¾	180,000	7 0	1,055,257	105,526	6 9·67
Durham and Northd.	115,700	5 6	125,000	5 0	159,500	5 0	225,332	6 1¼	1,174,257	117,426	5 6·54
Yorkshire, West Riding	579,000	5 0	785,628	5 0¼	230,905	5 0	307,717	5 0	4,451,250	445,125	4 10·65
Yorkshire, North Riding	2,739,039	5 10	2,785,307	5 0¼	3,094,678	5 0	4,072,888	5 0¼	25,558,467	2,555,847	5 1·46
Cumberland	890,566	12 9½	926,628	13 2	1,047,820	14 0½	1,221,303	14 9¼	8,282,201	828,220	12 11·80
Lancashire	667,356	10 0	767,625	10 0	784,507	10 0	871,938	15 0	6,813,226	681,323	10 7·68
Derbyshire	350,000	5 0	368,440	5 0	352,072	5 0	384,865	7 0	3,552,947	355,295	5 2·58
South Staffordshire	525,000	5 2½	340,578	5 1¼	350,000	5 6	450,000	7 0	6,150,578	615,058	6 1·77
North Staffordshire	794,509	5 4	786,881	5 5½	1,287,749	5 0	910,134	7 0	7,627,095	762,709	6 2·63
Warwickshire	15,500	5 0	14,795	5 0	15,000	5 0	17,500	7 0	156,295	15,629	5 3·01
Shropshire	250,000	5 0	278,541	5 0	318,483	5 0	337,627	7 9	2,694,958	269,496	5 1·64
Lincolnshire	192,213	5 0	205,699	5 0	253,024	4 11¾	248,330	5 0	1,429,913	142,991	5 2·55
Northamptonshire	416,765	5 0	449,116	5 0	540,259	5 0	761,248	5 0	3,720,940	372,094	5 0·88
Oxfordshire	..	..	..	..	10,167	5 0	38,804	5 0	72,393	7,239	5 11·56
Hampshire	..	..	..	..	..	..	..	..	17,509	1,751	9 1·38
Wiltshire	82,586	8 0	75,084	8 0	104,795	8 0¼	101,423	5 0	773,034	77,303	7 9·69
Herefordshire	..	..	..	..	..	..	..	..	321	32	9 1·91
Gloucestershire	156,169	9 0	167,288	9 0	172,023	8 0	183,503	9 0	1,527,597	152,760	9 0·06
Somersetshire	36,875	9 9	32,451	7 5¾	27,230	5 10¼	19,739	7 0	341,412	34,141	9 2·68
Devonshire	10,213	6 2½	11,178	6 6¾	7,104	6 0	10,194	6 10	144,205	14,421	6 10·18
Cornwall	6,426	6 3	8,310	5 11	4,619	7 10	11,214	5 9	189,439	18,943	7 4·81
Total	10,021,058	6 4·88	10,169,231	6 3·4	11,508,525	6 5·84	14,370,654	6 10·69	99,588,725	9,958,872	6 6·15

TABLE IV.—Continued.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

TIN ORE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	11,387	..	13,885	..	14,857	..	14,876	..	15,402	..	14,878	..	13,552	..	13,888	..	14,589	..	15,190	..	142,504	14,250	59 3 5·63
Devonshire	253	..	242	..	300	..	335	..	284	..	202	..	97	..	65	..	136	..	44	..	1,958	196	61 15 1·97
Total	11,640	..	14,127	..	15,157	..	15,211	..	15,686	..	15,080	..	13,649	..	13,953	..	14,725	..	15,234	..	144,462	14,446	59 4 2·04

ZINC ORE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	5,695	..	1,232	..	1,701	..	890	..	1,084	..	1,165	..	1,731	..	2,061	..	848	..	927	..	17,334	1,733	2 5 3·97
Devonshire	51	..	26	..	73	..	59	..	36	..	135	..	97	..	69	..	87	..	346	..	979	98	2 10 4·78
Cumberland	597	..	509	..	683	..	594	..	711	..	440	..	559	..	454	..	674	..	582	..	5,803	580	2 11 0·18
Derbyshire	1,225	..	1,500	..	1,250	..	794	..	1,000	..	500	..	44	..	49	..	50	..	57	..	6,469	647	1 16 0·51
Shropshire	..	..	..	..	210	..	102	..	165	..	192	..	337	..	215	..	138	..	399	..	1,758	176	3 0 9·15
Staffordshire	..	..	..	..	..	..	..	..	50	..	199	..	79	..	43	..	340	..	76	..	787	79	3 1 1·72
Wales: Anglesea	..	..	..	..	550	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	550	55	1 0 0·18
Wales: Carnarvon ..	..	..	109	..	1	..	30	..	..	..	..	..	..	..	9	..	..	..	62	..	211	21	2 10 2·84
Wales: Denbighshire ..	1,000	..	710	..	838	..	1,722	..	2,828	..	2,863	..	2,375	..	3,350	..	3,119	..	2,919	..	21,724	2,172	3 13 8·74
Wales: Flintshire	1,250	..	709	..	767	..	728	..	941	..	1,121	..	2,301	..	2,858	..	2,802	..	2,711	..	16,183	1,619	2 5 2·83
Wales: Montgomeryshire ..	..	..	..	..	..	..	..	..	82	..	27	..	249	..	136	..	111	..	700	..	1,305	131	3 1 1·79
Wales: Merionethshire ..	..	..	..	..	..	..	..	..	79	..	..	..	..	..	..	..	..	..	..	..	79	8	3 0 0·00
Wales: Brecknockshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	48	..	48	5	3 8 9·00
Wales: Cardiganshire ..	1,807	..	336	..	*757	..	300	..	715	..	116	..	223	..	77	..	69	..	213	..	3,856	386	2 8 11·31
Wales: Caermarthenshire	..	..	78	..	678	..	964	..	590	..	270	..	..	..	..	..	..	..	57	..	2,637	264	3 15 8·03
Wales: Pembrokeshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	103	..	..	..	..	..	103	10	1 9 10·83
Isle of Man	3,255	..	691	..	2,298	..	5,364	..	5,488	..	4,960	..	5,362	..	3,278	..	7,219	..	4,177	..	42,092	4,209	3 3 1·11
Ireland (Tipperary) ..	890	..	1,597	..	3,892	..	3,500	..	4,040	..	677	..	132	..	79	..	64	..	312	..	15,183	1,518	2 8 4·14
Scotland	..	..	..	..	..	..	..	..	33	..	105	..	..	..	..	..	12	..	..	..	150	15	3 19 0·80
Total	15,770	..	7,497	..	12,941	..	15,047	..	17,842	..	12,770	..	13,489	..	12,781	..	15,533	..	13,586	..	137,256	13,726	2 16 6·05

* Omitted in Total.

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

COPPER ORE.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	140,432	..	141,800	..	129,229	..	127,633	..	121,253	..	103,670	..	88,661	..	86,722	..	71,790	..	56,526	..	1,067,716	106,772	4 17 1·66
Devonshire	40,523	..	41,579	..	40,742	..	37,978	..	38,156	..	34,471	..	31,311	..	30,540	..	22,821	..	24,752	..	342,873	34,287	4 12 2·45
Cumberland	121	..	45	..	..	..	..	..	29	..	41	..	78	..	130	..	139	..	150	..	733	73	5 3 11·80
Lancashire	2,210	..	2,628	..	2,261	..	1,897	..	1,796	..	1,769	..	1,687	..	1,377	..	1,900	..	1,423	..	18,948	1,895	6 4 9·80
Yorkshire	..	..	..	..	..	..	76	..	80	..	..	..	..	..	..	..	..	..	80	..	236	24	5 3 11·80
Cheshire..	336	..	304	..	300	..	15,696	..	14,904	..	15,040	..	15,152	..	15,016	..	13,240	..	6,836	..	96,824	9,682	1 13 0·96
Shropshire	..	..	..	..	..	..	..	..	..	..	59	..	98	..	21	..	..	..	..	..	178	18	6 0 0·00
Staffordshire	..	..	..	..	..	..	10	..	..	..	..	..	12	..	25	..	..	..	4	..	51	5	7 3 6·35
Wales. Cardiganshire ..	67	..	185	..	..	..	300	..	300	..	223	..	156	..	123	..	132	..	117	..	1,603	160	8 8 11·95
Wales. Carnarvonshire ..	837	..	770	..	532	..	..	..	892	..	350	..	982	..	172	..	374	..	106	..	5,015	501	5 8 9·91
Wales. Flintshire	..	..	..	..	151	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	153	15	1 15 5·10
Wales. Montgomeryshire	115	..	..	..	..	..	54	..	..	..	..	..	..	..	432	..	155	..	120	..	876	88	4 7 3·94
Wales. Anglesea	5,689	..	5,757	..	5,354	..	4,565	..	7,785	..	9,738	..	7,274	..	7,595	..	6,014	..	7,175	..	66,946	6,695	4 8 3·24
Isle of Man	1,485	..	1,021	..	1,293	..	127	..	1,317	..	294	..	400	..	462	..	458	..	373	..	7,230	723	5 1 0·28
Scotland, Renfrewsh..	401	..	173	..	..	..	..	..	14	..	..	..	..	..	..	..	..	..	..	..	588	59	4 11 1·88
Ireland. Cork..	7,283	..	8,412	..	8,874	..	7,929	..	5,798	..	5,424	..	5,998	..	3,365	..	455	..	2,116	..	55,654	5,565	8 16 4·07
Ireland. Waterford.. ..	6,670	..	5,176	..	5,259	..	5,004	..	3,596	..	5,710	..	5,354	..	5,069	..	5,299	..	1,963	..	49,100	4,910	8 6 7·45
Ireland. Wicklow	1,510	..	51	..	682	..	1,304	..	2,063	..	3,234	..	1,039	..	92	..	1,786	..	4,039	..	15,800	1,580	2 19 11·62
Ireland. Kerry	67	..	144	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	211	21	21 13 2·10
Sundries undivided ..	23,741	..	16,126	..	16,270	..	12,031	..	315	..	353	..	342	..	6,194	..	5,390	..	918	..	81,680	8,168	6 3 4·66
Total	231,487	..	224,171	..	210,947	..	214,604	..	198,298	..	180,378	..	158,544	..	157,335	..	129,953	..	106,698	..	1,812,415	181,241	4 18 0·77

TABLE IV.—Continued.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

LEAD ORE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	6,691	..	6,030	..	6,260	..	5,302	..	6,546	..	6,736	..	8,645	..	8,416	..	9,023	..	8,481	..	72,130	7,213	12 5 2·18
Devonshire	2,763	..	2,079	..	1,578	..	1,656	..	1,848	..	723	..	803	..	1,523	..	1,081	..	1,235	..	15,289	1,529	12 14 3·84
Somersetshire	860	..	750	..	700	..	2,374	..	1,050	..	1,132	..	884	..	1,135	..	1,538	..	1,337	..	11,760	1,176	12 16 8·55
Derbyshire	7,376	..	7,048	..	6,180	..	6,006	..	6,283	..	6,431	..	4,917	..	5,933	..	6,473	..	6,352	..	62,999	6,300	12 13 8·03
Staffordshire	40	..	60	..	..	..	502	..	296	..	202	..	83	..	116	..	526	..	193	..	2,018	202	12 17 10·31
Shropshire	4,616	..	4,158	..	4,209	..	3,809	..	3,716	..	4,038	..	4,506	..	4,943	..	5,606	..	5,729	..	45,330	4,533	12 12 7·62
Cheshire	107	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	107	11	12 10 3·37
Lancashire	..	..	..	..	..	..	..	..	..	..	250	..	690	..	441	..	..	..	..	..	1,331	138	12 7 2·37
Yorkshire	8,801	..	9,255	..	8,982	..	8,679	..	7,618	..	9,735	..	7,539	..	7,694	..	8,563	..	6,594	..	83,460	8,346	12 14 2·69
Cumberland	6,324	..	7,174	..	6,691	..	6,409	..	6,173	..	5,621	..	5,683	..	5,520	..	4,445	..	3,689	..	57,729	5,773	12 14 8·52
Westmoreland ..	2,393	..	2,018	..	2,315	..	2,057	..	1,881	..	1,940	..	2,418	..	2,053	..	2,519	..	2,547	..	22,141	2,214	12 13 3·87
Durham and Northumberland	19,537	..	21,772	..	22,774	..	23,030	..	21,502	..	22,555	..	22,574	..	23,721	..	20,793	..	25,590	..	223,848	22,385	12 13 9·09
Wales: Carnarvon ..	173	..	236	..	308	..	190	..	237	..	261	..	303	..	238	..	161	..	181	..	2,288	289	12 13 10·04
Wales: Denbighshire ..	7,647	..	7,925	..	7,919	..	9,694	..	7,508	..	6,474	..	8,987	..	8,266	..	7,260	..	6,943	..	78,623	7,862	12 14 6·18
Wales: Flintshire	4,411	..	5,212	..	4,648	..	5,420	..	6,137	..	5,295	..	4,202	..	4,321	..	4,749	..	4,361	..	48,756	4,875	12 14 5·64
Wales: Montgomeryshire	2,452	..	4,289	..	3,649	..	3,102	..	3,024	..	3,075	..	3,588	..	4,019	..	5,521	..	7,174	..	39,893	3,989	12 12 0·16
Wales: Merionethshire ..	207	..	197	..	29	..	17	..	3	..	15	..	25	..	56	..	..	..	83	..	632	63	12 10 3·79
Wales: Cardiganshire ..	7,755	..	8,299	..	7,132	..	7,464	..	7,835	..	7,700	..	7,839	..	7,231	..	8,180	..	7,307	..	76,742	7,674	12 13 7·60
Wales: Caermarthenshire	1,442	..	1,298	..	1,000	..	971	..	929	..	805	..	822	..	500	..	606	..	665	..	9,033	904	12 14 9·97
Wales: Pembrokeshire ..	97	..	339	..	250	..	351	..	322	..	308	..	282	..	294	..	360	..	342	..	2,945	294	12 14 1·18
Wales: Brecknockshire ..	..	..	2	..	..	..	7	..	12	..	10	..	6	..	..	..	..	..	..	..	37	4	12 19 5·51
Wales: Radnorshire ..	37	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	37	4	12 10 7·25
Isle of Man	2,718	..	2,509	..	2,562	..	3,118	..	3,143	..	3,494	..	3,799	..	4,290	..	4,302	..	4,604	..	34,539	3,454	12 12 6·49
Ireland	2,403	..	2,644	..	2,412	..	2,202	..	2,024	..	1,823	..	1,883	..	2,039	..	1,979	..	1,415	..	20,874	2,087	12 14 3·49
Scotland	1,761	..	1,767	..	1,455	..	2,073	..	2,364	..	2,424	..	2,954	..	2,437	..	3,181	..	3,354	..	23,770	2,377	12 12 4·78
Sundries under 10 Tons	55	..	250	..	230	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	535	53	12 14 11·89
Total	90,666	..	95,311	..	91,283	..	94,433	..	90,451	..	91,047	..	93,432	..	95,236	..	96,866	..	98,176	..	936,901	93,690	12 13 8·05

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

IRON PYRITES.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	16,902	..	14,649	..	7,897	..	8,656	..	9,200	..	9,534	..	8,388	..	7,347	..	3,258	..	5,096	..	90,927	9,093	0 18 11·33
Devonshire	1,573	..	1,306	..	407	..	1,078	..	1,793	..	915	..	778	..	685	..	4,392	..	2,420	..	15,347	1,535	0 15 9·06
Cumberland	3,246	..	1,805	..	2,035	..	237	..	..	..	..	..	..	..	..	..	..	..	..	..	7,323	732	0 19 10·75
Durham and Northumberland	3,250	..	3,500	..	8,597	..	7,560	..	6,500	..	5,000	..	2,500	..	1,760	..	5,641	..	3,000	..	47,308	4,731	0 17 5·08
Yorkshire	3,000	..	3,450	..	6,549	..	5,558	..	10,053	..	3,000	..	3,500	..	3,000	..	2,950	..	3,737	..	44,797	4,480	0 11 10·89
Lancashire	3,760	..	2,670	..	3,000	..	2,500	..	2,750	..	2,750	..	2,750	..	2,000	..	2,250	..	2,250	..	26,680	2,668	0 8 11·12
Shropshire	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	71	..	71	7	0 9 0·17
Wales. Anglesea	..	..	..	..	402	..	440	..	450	..	136	..	118	..	82	..	..	..	200	..	1,828	183	0 11 4·93
Wales. Carnarvon ..	751	..	..	..	897	..	785	..	706	..	906	..	962	..	1,225	..	1,166	..	1,190	..	8,588	859	0 9 9·99
Wales. Montgomeryshire	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,830	..	1,830	183	0 9 0·06
Wales. Denbighshire and Flintshire	850	..	1,869	..	1,000	..	750	..	750	..	475	..	750	..	..	..	..	..	..	..	6,444	644	0 12 0·40
Ireland—Wicklow ..	91,803	..	69,184	..	64,592	..	66,894	..	81,993	..	112,686	..	97,143	..	60,385	..	56,291	..	38,634	..	739,605	73,961	0 11 0·05
Total	125,135	..	98,433	..	95,376	..	94,458	..	114,195	..	135,402	..	116,889	..	76,484	..	75,948	..	58,428	..	990,748	99,075	0 12 2·63

MANGANESE.

District.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall and Devonshire	925	..	..	..	..	..	..	..	..	..	..	..	770	..	1,700	..	..	..	..	..	3,395	340	4 0 5·30
Carnarvonshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,558	..	4,838	..	6,396	640	4 5 7·99
Merionethshire ..	..	..	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	..	5	..	4 0 0·00
	..	..	..	..	..	..	..	..	..	..	..	..	33	..	..	..	..	..	..	..	33	3	4 0 0·00
Total	925	..	..	..	..	..	..	..	..	..	..	..	808	..	1,700	..	1,558	..	4,838	..	9,829	983	4 3 10·07

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

ARSENIC.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	Tons.	ꝑ Ton. £ s. d.
Cornwall... ... }	...	...	900	...	...	...	...	...	826	...	1,116	...	1,199	...	1,267	...	1,189	...	1,813	...	8,310	831	2 1 8·42
	1,450	...	...	...	1,444	...	1,858	...	...	...	...	...	...	...	...	...	...	...	...	...	4,752	475	2 16 8·20
Devonshire ... }	...	...	...	...	...	...	...	...	...	...	...	...	56	...	473	...	1,372	...	2,237	...	4,138	414	5 11 9·11
Prod. at Swansea	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,560	...	...	...	...	...	1,560	156	2 2 3·69
Estimated ...	...	...	...	...	...	...	...	...	...	...	...	...	1,000	...	...	...	...	...	...	...	1,000	100	2 0 0·00
Total	1,450	...	900	...	1,444	...	1,858	...	826	...	1,116	...	2,255	...	3,300	...	2,561	...	4,050	...	19,760	1,976	2 19 11·24

GOSSANS, OCHRES, UMBERS, &c.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	Tons.	ꝑ Ton. £ s. d.
Cornwall ... }	3,016	...	...	...	1,829	...	824	...	1,334	...	1,676	...	1,381	...	1,374	...	358	...	181	...	11,973	1,197	1 6 4·09
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,100	...	...	...	...	...	1,100	110	0 18 2·18
Devonshire }	...	...	...	...	124	...	71	...	...	...	97	...	69	...	27	...	211	...	21	...	620	62	0 15 11·61
Isle of Man ...	116	...	...	...	...	...	...	...	...	...	130	...	...	...	149	...	140	...	142	...	677	68	2 17 1·96
Anglesea	...	...	...	...	2,471	...	2,153	...	...	...	3,125	...	4,032	...	4,042	}	...	...	...	...	15,823	1,582	0 17 10·14
Pt. Cornwall ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		}	5,000	...	4,500	...	9,500	950	0 16 3·79
Pt. Devonshire ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	}	...	...	...	...	...	...	...
Total ...	3,132	...	...	...	4,424	...	3,048	...	1,334	...	5,028	...	5,482	...	6,692	...	5,709	...	4,844	...	39,693	3,969	1 0 8·31

COPROLITES.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	ꝑ Ton	Tons.	Tons.	ꝑ Ton. £ s. d.
Bedfordshire ...	...	...	...	...	...	...	...	...	...	...	...	...	7,000	...	7,500	...	...	...	...	...	14,500	1,450	1 17 11·77
Cambridgeshire }	...	...	...	...	...	...	...	...	...	...	...	...	30,000	...	30,000	...	...	...	...	...	60,000	6,000	1 18 0·80
Hertfordshire ... }	37,500	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	37,500	3,750	2 0 0·00
Suffolk ... ... }	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Estimated ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35,000	...	35,000	3,500	1 8 6·84
Total	37,500	...	...	...	...	...	...	...	...	...	...	...	37,000	...	37,500	...	...	...	35,000	...	147,000	14,700	1 16 3·59

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

BARYTES.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Northumberland	..	..	..	..	..	..	..	..	..	..	..	..	4,579	..	1,476	..	2,485	..	2,706	..	11,246	1,125	0 13 7·17
Durham	..	..	..	..	..	..	..	..	4,034	..	..	..	..	..	..	..	..	..	..	..	4,034	403	0 14 11·97
Cumberland ..	56	..	15	..	..	..	3	..	65	..	..	..	802	..	213	..	122	..	509	..	1,785	178	0 13 4·94
Yorkshire	795	..	500	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,295	129	0 14 8·25
Derbyshire ..	7,500	..	6,425	..	..	..	..	..	..	..	..	..	4,500	..	10,736	..	2,939	..	2,861	..	34,961	3,496	0 16 1·76
Shropshire.. ..	85	..	747	..	..	..	497	..	2,670	..	..	..	1,226	..	1,810	..	329	..	439	..	7,803	780	0 18 10·93
N. Wales	1,695	..	950	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2,645	264	0 14 8·30
Montgomeryshire	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	112	..	..	..	112	11	0 10 2·14
Scotland .. Kirkcudbright	175	..	150	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	325	32	0 14 7·75
Isle of Arran ..	625	..	730	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,355	136	0 14 8·24
Ireland	520	..	450	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	970	97	0 14 8·16
Total	11,451	..	9,967	..	..	..	500	..	6,769	..	..	..	11,107	..	14,235	..	5,987	..	6,515	..	66,531	6,653	0 13 11·96

CLAYS (FINE AND FIRE).

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Per Ton.	Tons.	Tons.	Per Ton. £ s. d.
Cornwall	82,344	..	83,008	..	81,820	..	118,750	..	124,816	..	142,024	..	161,816	..	130,479	..	135,575	..	144,209	..	1,204,841	120,484	0 17 7·54
Devonshire ..	33,549	..	29,204	..	33,264	..	46,324	..	50,608	..	57,203	..	60,962	..	57,000	..	56,200	..	60,998	..	485,312	48,531	0 10 5·56
Dorsetshire ..	226,712	..	241,591	..	205,423	..	200,500	..	200,500	..	200,500	..	150,000	..	150,000	..	150,000	..	150,000	..	1,875,226	187,523	0 4 7·68
Staffordshire, Yorkshire .., Derbyshire, Do. adjacent Counties ..	348,000	..	500,000	..	500,000	..	750,000	..	750,000	..	750,000	..	750,000	..	675,000	..	858,225	..	844,793	..	6,726,018	672,602	0 5 3·24
Sundry	..	..	..	..	..	..	..	..	..	..	..	..	56,522	..	..	..	..	..	..	..	56,522	5,652	3 6 11·83
Total	690,605	..	853,803	..	820,507	..	1,115,574	..	1,125,924	..	1,149,727	..	1,179,300	..	1,012,479	..	1,200,000	..	1,200,000	..	10,347,919	1,034,792	0 7 2·10

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

SALT.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Tons.	Pr.Ton.
		£		£		£		£		£		£		£		£		£		£			s. d.
Cheshire	..	..	..	..	..	..	..	..	..	..	..	..	1,250,000	..	1,250,000	..	1,037,528	..	1,250,000	..	4,787,528	478,753	11 3·92
Worcestershire ..	..	..	..	..	..	..	..	..	..	..	..	..	125,250	..	240,000	..	195,000	..	220,000	..	78,250	78,025	11 3·16
Ireland	..	..	..	..	..	..	..	..	..	..	..	..	19,689	..	23,840	..	17,472	..	19,450	..	80,451	8,045	11 4·48
Total.. ..	..	..	..	..	..	..	..	..	..	..	..	..	1,394,939	..	1,513,840	..	1,250,000	..	1,489,450	..	5,618,229	564,823	11 3·85

SILVER ORE.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr Ton.	Tons.	Tons.	Per Ton.
Cornwall	29	..	200	..	88	..	51	..	..	..	..	..	..	..	..	..	..	..	..	..	368	37	£ s. d. 60 12 4·04

ANTIMONY.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869		1870.		Total of 10 Years.	Average.	
	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons	Pr.Ton.	Tons.	Pr.Ton.	Tons	Pr.Ton.	Tons.	Pr.Ton.	Tons	Pr.Ton.	Tons.	Pr.Ton	Tons.	Tons.	Per Ton.
Cornwall	15	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	15	2	£ s. d. 3 0 0·00

FLUOR SPAR.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years	Average.	
	Tons.	Pr.Ton	Tons.	Pr Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr Ton.	Tons.	Tons.	Per Ton.
Cornwall	..	..	..	..	..	..	21	..	3	..	2	..	..	..	60	..	..	..	..	..	86	9	£ s. d. 1 3 11·44

NICKEL ORE.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866		1867.		1868.		1869		1870.		Total of 10 Years.	Average.	
	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons.	Pr.Ton.	Tons	Pr.Ton	Tons.	Pr.Ton.	Tons.	Tons	Per Ton.
																							£ s. d.
Cornwall	0·785	..	..	..	..	..	..	..	..	..	..	..	1·862	..	..	..	..	..	..	..	2·617	·265	14 7 1·41
Linlithgow	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·600	..	0·600	·060	45 0 0·00
Total.. ..	0·785	..	..	..	..	..	..	..	..	..	..	..	1·862	..	..	..	..	..	0·600	..	3·217	·325	20 0 0·45

TABLE IV.—CONTINUED.

ANNUAL TONNAGE PRODUCE OF EACH DISTRICT, *AND AVERAGE VALUE PER TON, ASSUMED IN THE MINERAL STATISTICS.*

OXIDE OF IRON.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870		Total of 10 Years.	Average.	
	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Tons.	Pr. Ton.
Cornwall	..	..	..	..	..	..	20	..	..	..	..	..	..	..	..	..	..	..	..	..	20	2	s. d. 5 0

TUNGSTATE OF SODA.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Tons.	Pr. Ton.
Cornwall	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	14	..	25	..	39	4	£ s. d. 15 3 0·92

URANIUM.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons	Tons.	Pr. Ton.
Cornwall	..	..	..	..	0·158	..	..	..	..	..	..	..	..	..	..		..	..	..	..	0·158	·016	£ s. d. 145 11 4·70

WOLFRAM.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Tons.	Pr. Ton.
Cornwall . ..	6	..	12	..	13	..	2	..	2	..	..	..	10	..	9	..	11	..	26	..	91	9	£ s. d. 7 13 4·88

GOLD QUARTZ.

DISTRICT.	1861.		1862		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average	
	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Tons.	Pr Ton.
Merionethshire ..	..	..	803	..	335	..	..	..	4,280	..	2,928	..	3,241	..	1,191	..	..	..	..	..	12,828	1, 83	£ s. d. 2 2 2·04
Sutherlandshire ..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total ..	..	..	803	..	885	..	..	..	4,230	..	2,928	.	3,241	..	1,191	..	..	..	..	..	12,828	1,283	2 12 2·04

EARTHY MINERALS.

DISTRICT.	1861.		1862.		1863.		1864.		1865.		1866.		1867.		1868.		1869.		1870.		Total of 10 Years.	Average.	
	Tons	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons.	Pr. Ton	Tons	Pr. Ton	Tons.	Pr. Ton	Tons.	Tons.	Pr. Ton.
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

The Chairman said, he felt sure they were very much obliged to the writer of the valuable paper they had just heard read. It would form an item of considerable importance in their proceedings for that year; he thought, they might point with satisfaction to the conspicuous place occupied by coal, which was represented as forming something like three-fourths of the total mineral out-put of the country. These statistics, which exhibited such an immense out-put of mineral wealth, would very clearly indicate the source from which the prosperity of England was at present derived. He thought there was no need of discussion, and all they had to do that day was to pass a vote of thanks to the writer, and then proceed to the next paper, which was unanimously concurred in.

Mr. Howard, in acknowledging the compliment, said he would endeavour to attend the discussion, to give any further explanation that might be needed.

Mr. John Daglish read a translation of a paper "On the Application of Machines worked by Compressed Air in the Collieries of Sars-Longchamps and Bouvy, at St. Vaast, in Belgium, by Mons. F. L. Cornet."

ESTABLISHMENT OF AI

OF THE CO

Sars Longchamps

A. *Situation of the undergr*
B.C. *Situation of those t*

FIG. I. *Section of Coal Fi*
at the landing

FIG. 2. *Horizontal Plan*
of the Galleries wh

N.B. The thick dotted line
ranges of Pipes.

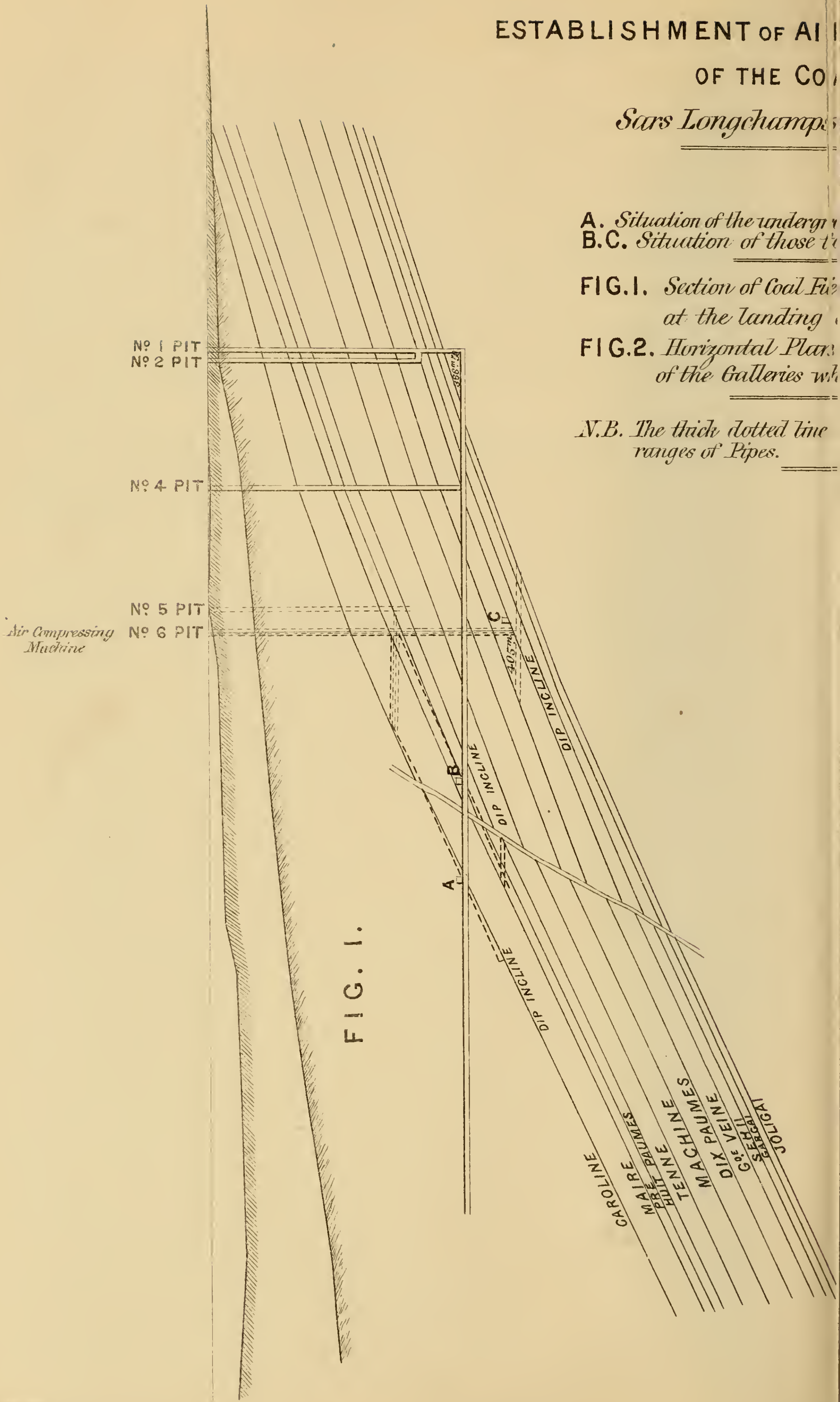


FIG. I.

COMPRESSING MACHINERY

COMPANIES OF

nd Bouvy at St. Vaast.

d Engine actually working.
erected.

follows the Main Level
366m 50.

ewing the general position
compression is arranged.

dicates the different

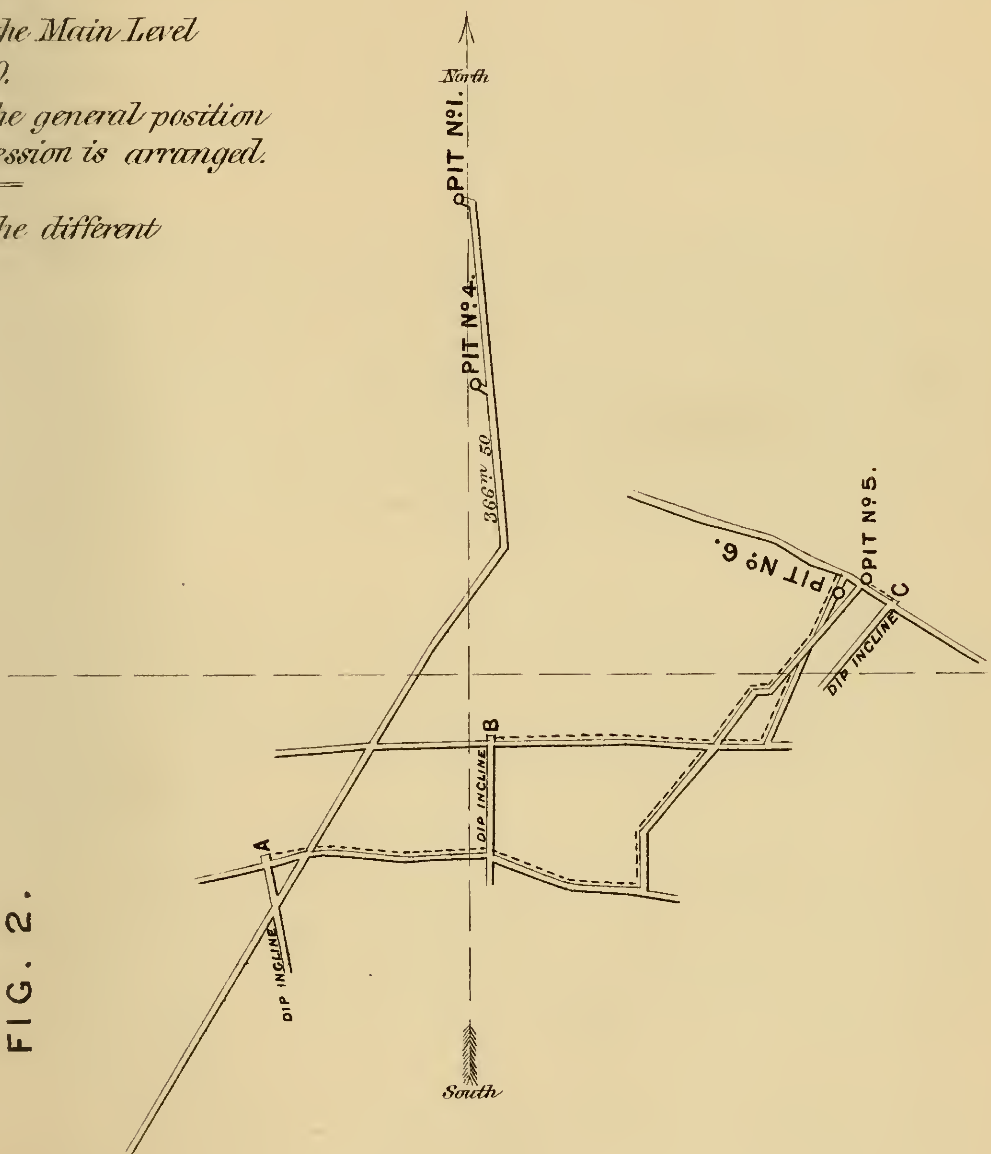


FIG. 2.

Andw Reid, Newcastle

ON THE APPLICATION OF MACHINES WORKED BY COMPRESSED AIR IN THE COLLIERIES OF SARS-LONGCHAMPS AND BOUVY, AT SAINT-VAAST, IN BELGIUM.

BY M. F. L. CORNET

(Translated from the French by Mr. John Daglish).

[Sometime since, the translator, having occasion to erect machinery for working with compressed air, had his attention called to the valuable paper read by M. Cornet to the "Société des Anciens Elèves de l'Ecole Spéciale des Mines, du Hainaut," and published in their Transactions. More recently, air-compressing machinery, on a scale of considerable magnitude, has been erected at Ryhope Colliery with much success, and has been fully described in a paper read to your Institute.

Perhaps, at this juncture, M. Cornet's paper may aid in the discussion that will arise on this interesting and important subject.]

TOWARDS the end of the year 1863 the Colliery Company of Sars-Longchamps and Bouvy resolved to drive below the "main level" gallery (driven at that concession at a depth of 366 metres) some drifts to the dip, for the purpose of working the different seams intersected by that gallery.

It was decided that a system of working should be arranged so as to produce 72,000 tons of coals annually, and that it should be applied first to the seams farthest from the pits, *i.e*, to the seams "*Huit paumes,*" "*Pré,*" and "*Marie,*" forming a group intersected by the "level" at 600 metres, and also in the "*Caroline*" cut at 770 metres (see Plate XXXIII.).

The seams are very regular in positions. Their inclination varies from 25° to 32°, and their thickness of coal from 0·38 metres to 0·55 metres. They yield refuse stones, which it is necessary to draw to the surface to the extent of about 30 per cent. of the weight of coal. The floor is generally good; but the roof very variable. In some parts it is strong and requires hardly any kind of support; in other parts it is bad and can only be kept up by numerous props. The overlying strata are full of water; but there is not an important discharge.

In the calculations which have been made to estimate the expenditure of mechanical work required in drawing from the dip, the maximum height of the panel is taken at 160 metres, the average inclination of the seam at 28°, and the quantity of water to be extracted from the workings in twenty-four hours at 100 cubic metres.

The quantities to be raised annually are, therefore,

72,000	tons of	coal.
21,600	,,	refuse stone.
36,500	,,	water.
Total 130,100 tons.		

Taking 290 working days per year, the quantity to raise per day, therefore, is 448,620 kilogrammetres. With an inclination of 28°, a dip drift of 160 metres in length would be 75·10 metres in vertical depth.

Suppose a daily working of twelve hours, of which four hours are occupied in changing and short stops, there remain eight hours for effectual working. The theoretical quantity of mechanical power to be produced per second is, therefore,

$$\frac{448{,}620 \text{ kil} \times 75{\cdot}10 \text{ m.}}{8 \text{ hours} \times 3{,}600 \text{ secs.}} = 1{,}170 \text{ kilogrammetres.}$$

The resistance of the wagons and ropes on the inclined planes, and the friction on the axles, absorb 20 per cent. of the theoretical power, so that the practical power required would be $1{,}170 + \frac{20}{100} \times 1{,}170 =$ 1,404 kilogrammetres. This is equal to 18·72 horse-power per second.

This large requirement excludes at once the idea of using animal power. A man working a winch can only produce, on an average, 6 kilogrammetres per second; it would require, therefore, 234 men to obtain a total power of 1,404 kilogrammetres.

A horse attached to a wagon produces 40·50 kilogrammetres per second; on these conditions it can work eight hours on the surface, but at the bottom of the mine, not more than six hours of effective work should be calculated on. It would require, therefore, 47 horses to obtain the work of 18·72 steam horse-power; and for 47 horses employed, there would be continually 3 in the infirmary, which would bring the actual number required to 50. A horse in a mine costs, on an average, 1,242 francs annually, keep and upholding included, but without driver. The total expense, per annum, for 50 horses would be 62,100 francs, or nearly 0·08 francs per hectolitre of coal drawn out from the dip.

It was necessary, therefore, to have recourse to one of the following mechanical powers :—

1st.—Steam engines placed at the top of the dip inclines with boilers adjacent to them.

2nd.—Steam engines similarly placed, with boilers at the bottom of the winding shaft or on the surface.

3rd.—Steam engines placed at the bottom of the winding shaft, with boilers adjacent or on the surface, and acting by ropes carried along the level to the dip inclines.

4th.—Steam engines placed on the surface, and acting by ropes carried down the pit and along the levels to the dip inclines.

5th.—Hydraulic engines placed at the top of the dip inclines and worked by water coming from a higher cistern.

6th —Engines analogous to steam engines placed at the top of the dip inclines, but working by compressed air, produced by an engine specially constructed for this purpose on the surface.

The different systems were seriously considered, and it was decided that only compressed air could be employed. It is not necessary to enter on the reasons which led to this choice; they arose entirely from the position of the works of the Sars-Longchamps Company.

Having adopted, in principle, the application of engines worked by compressed air, the Company, before absolutely deciding, determined that an excursion should be made to the mines of England, where apparatus of this kind is employed. M. Cornet, in describing the observations made in that visit, stated that he was accompanied by Messrs. A. Halbrecq, engineer of the workshops at Jemappes ; and Victor Plumat, formerly of the School of Mines, of Mons, attached to the "Levant du Flênu Co."

Until recently the use of mechanical appliances in the interior of mines has been very little adopted in Belgium. The practice of the miner has been to obtain traction-power, solely from the muscular force of men and animals, or by gravity. But it is not so in the coal mines in England. The most of the important mines in the basins of Durham and Newcastle, Lancashire and South Wales, employ, in their interior workings, numerous machines, the power and dimensions of which astonish the engineers of the Continent who visit them.

The motive power is steam or compressed air. With the first, the machines are placed on the surface, and transmit their power to the interior of the works by means of ropes; or they are placed in the galleries adjacent to the upcast shafts, which serve for the escape of the gaseous products of combustion. In the second case, the air is compressed on the surface and conveyed through pipes into the interior of the mines, where it acts on the machinery usually placed far from the ventilating shafts.

The steam engines are much the more numerous and powerful agents employed; compressed air machines being of more recent application do not exist in great numbers, and are not of dimensions to be compared with those of the steam engines. However, at the commencement of the year 1864, a dozen machines of this class were in operation in the coal-field of Lancashire alone, and others were either projected or in course of construction. But with their system of working, and with the large quantity of air in the workings which they generally have, English engineers will always prefer steam engines to all other machines, when they can place them on the surface, or underground, in places adjacent to the ventilating shafts. Compressed air can only be advantageously employed when far from the ventilating shafts, or in places too much charged with gas to permit the employment of boilers. Still, however, many of the English engineers are convinced that air machines will spread rapidly in the mines of Great Britain.

The engines used underground in England are chiefly employed for conveying minerals on level roads or inclined planes, some are employed in drainage, and others more rarely in hewing coal; these latter are still under trial, but the others have proved their success.

The principal application of engines for transport is on inclined planes, which sometimes exceed in length 2,000 metres. Dip working, far from being the exception as in Belgium, is almost universal in England. That part of the seam situated to the dip of the pit is nearly always worked by dip inclines. Generally, a "hanging on" is arranged at the lowest seam that is intended to be worked; at that level the higher seams are cut by a level drift driven across, and the parts to the dip and to the rise are wrought successively or simultaneously, sometimes descending in the seam to a depth that would appear impossible to many persons who have not visited the English mines.

This method of working appears very rational for the English collieries, and would be quite as much so in many of the Belgian collieries; and, sooner or later, perhaps sooner than some may think, certain circumstances, perhaps not altogether connected with mines, will oblige the Belgian adventurer to adopt this application.

It is not intended to discuss the advantages and disadvantages of "dip workings," nor to describe the steam engines employed in England in similar works; but it may be useful to say a few words on certain underground arrangements which have been visited.

(The writer then shortly describes the steam engines at Pendleton, which description it is unnecessary to give here.)

The first important application of compressed air as a hauling power appears to go back to the year 1851. The apparatus erected at Govan Colliery, near Glasgow, has been described in detail in the "Revue Universelle de Liége," Vol. 1; the air, compressed to $1\frac{1}{4}$ atmospheres above the atmospheric pressure, is forced into the mine at a depth of 161 metres, and works an engine erected at a "staple" in the interior about 600 metres from the shaft.

The compressing engine is a beam engine; it works two single-acting air pumps, acting alternately; these pumps are 0·533 metres in diameter, and 0·457 metres length of stroke. Each suction and delivery valve consists of 44 spheres of brass of 0·05 metres diameter, always covered with a layer of water; the use of the water is to reduce as much as possible the injurious spaces, to prevent all escape of air, and to cool, to a certain extent, the air heated by compression; the temperature does not exceed 30° to 45° centigrades.

The compressing machine at Govan, perfect as regards its mechanism, was very costly to erect; other apparatus met with in Lancashire was much simpler and less costly, and easily kept in repair at little cost.

At Scot Lane Colliery, near to Blackwood, to the west of Manchester, the most extensive application of compressed air for working in the interior of mines was met with. The air is compressed on the surface by two horizontal steam engines, one of which also works the drainage pumps, and the other a circular saw. The steam cylinders and the air cylinders are placed one behind the other, and the pistons are placed on the same piston rod; the compressing cylinders are double acting, and are enclosed in a bath through which there is a constant current of water. The suction is made through holes of 0·01 metres diameter, pierced in great numbers in the end of the cylinders; the falls are simple sheets of India-rubber, of 0·012 metres in thickness, fastened at the centre. The delivery is effected by ordinary brass valves, the lift of which is regulated by a screw bolt which passes through the valve corner.

Before entering into the mine the air passes into a receiver formed of two old steam boilers, one 1·10 metres diameter and 5 metres long, the other 1·50 metres diameter and 9 metres long; each of these boilers is fitted with a safety-valve and sludge-cock.

The compressing pistons are constructed similar to steam pistons; they have springs and rings of cast iron; the inside of the cylinders are not lined with brass as in the Govan machine.

At the time of M. Cornet's visit, the first of these compressing engines only was at work; the other is only employed when the quantity of work to be drawn out of the mine requires it. The velocity was 20 double strokes per minute (1·42 metres per second), the pressure of air in the receiver was 52 lbs. per square inch (or $3\frac{1}{2}$ atmospheres), the refrigerating water entered the bath at 12° c. and left it at 56° c. A sensation of heat was felt when the hand was placed on the discharge pipe between the cylinder and the receiver, but it could be kept there without inconvenience. On placing the hand on the pipe leading from the receiver to the mine, no heat could be perceived; the air, therefore, was cooled down in its passage through the receiver.

The following are the dimensions of the compressing engines :—

1st Machine—Steam Cylinder, diameter	... ...	0·61 metres.
" " stroke	... ...	1·52 "
1st Machine—Air Cylinder, diameter	... ...	0·305 "
" " stroke	... ...	1·52 "
2nd Machine—Steam Cylinder, diameter	... ...	0·41 "
" " stroke	... ...	0·915 "
2nd Machine—Air Cylinder, diameter	... ...	0·37 "
" " stroke	... ...	0·915 "

The pipes conducting the air from the cylinders to the receivers are of cast iron, 0·075 metres diameter; they are fastened by flanges and bolts, with India-rubber weazes. The same material is used for the joints of all the apparatus for carrying the air, except for the pipes which go down the shaft. These are of wrought iron, and are fastened by screwed collars. These pipes are 0·05 metres interior diameter; the shaft is 137 metres in depth.

The compressed air is used to drive five small machines in the mine, two of which are used for hauling coals from the dip, and three for pumping water.

There is nothing in these machines to distinguish them from ordinary steam engines. The first we visited is placed 125 metres from the shaft; it works an endless rope on a dip inclined plane, 457 metres in length, inclined 0·05 per metre; it has a horizontal cylinder of 0·20 metres diameter, and 0·45 metres stroke, and works by means of mitred wheels, a vertical shaft carrying a pulley with a deep groove, round which the endless cord passes one and a half times. The rope is of wire, 0·025 metres in diameter; the wagons are attached at a distance of 15·50 metres apart, they contain 5 to 6 hectolitres.

All the machine is contained in a timbered excavation, of 3 metres long by 2·75 metres wide, and 1·50 metres high.

A second hauling machine is erected in another part of the mine; the cylinder is horizontal, of 0·34 metres diameter and 0·75 metres stroke; it works by means of toothed wheels, a double drum 1·50 metres diameter, round which are wire ropes which haul trains consisting of six wagons, on a dip incline of 915 metres inclined 0·05 per metre; each drum can be put out of gear on the shaft, which allows the descent of the empty train by the brake. This arrangement, which is adopted in nearly all the engines employed in the interior of mines on inclined planes, is for the purpose of expediting the working from the bottom of the planes, and to enable the haulage from several levels.

The three other compressed air machines at Scot Lane Colliery are erected at the bottom of dip inclines, where they pump water; these engines are horizontal, with cylinders 0·20 metres diameter and 0·45 metres stroke; they work ordinary forcing pumps.

It was not possible to measure the useful effect of the interior machines at Scot Lane, nor the difference in pressure of the air at the two extremities of the conducting pipe; but much practical information on the subject of compressed air machines was obtained.

All the joints of the bolted flange pipes which carry the compressed air should be made of India-rubber of a fixed thickness (·005 metres to ·012 metres); cement of all kinds and India-rubber weazes of 1 to 3 millimetres allow the escape of the compressed air. It is indispensable to place on the receiver, on the surface, and on the pipes near the underground machines, taps which can be opened from time to time to blow off the water which condenses there. If this precaution is neglected, the exhaust parts of the machine are obstructed with ice which forms there.

One of the machines at Scot Lane was only able to work properly after a waste cock had been placed on the bent pipe below the valve chest.

Compressed air machines ought to be calculated to work at pressures which do not exceed 45 to 60 lbs. per square inch. At Scot Lane an attempt was made to work at 100 to 120 lbs., but there were frequent interruptions from the deposition of ice in the machine and discharge pipes.

The inconvenience of using air at too high a pressure was also felt at the machines in the Haigh Collieries, near Wigan. They were at first erected to work, and did actually work, at 8 to 9 atmospheres. M. Devilliz has given a description of these in his work on the "Employment of Underground Machines in Mines." But in May, 1864, the necessary changes had been made to work at 3 to 4 atmospheres. These machines are erected at the Bridge Pit of the Haigh Collieries. The air is compressed by a vertical engine with a double-acting air-pump of 0·23 metres diameter and 1·83 metres length of stroke, making 22 double strokes per minute (1·34 metres per second). The conducting pipes are of cast iron, attached by flanged joints with weazes of India-rubber. Their total length is about 720 metres. Circumstances prevented a visit to the interior of the mine.

An air compressing machine, arranged specially for this purpose, is erected at Ince Hall Pit, near Wigan. It is horizontal, and the compressing cylinder is arranged exactly like the one at Scot Lane. The diameter of the air piston is 0·455 metres, that of the steam piston 0·66 metres, and the length of stroke 1·47 metres. The pressure of air is 45 to 60 lbs. per square inch, and that of the steam 45 to 50 lbs.

This machine supplies air to a "hewing machine" which was visited, but is not described here, as it is foreign to this enquiry.

Before describing the apparatus erected by the Sars-Longchamps Company, it will be well to enter on some theoretical considerations on the application of compressed air.

The work done in compressing air may be divided into two heads :—

1st. The work necessary to compress the air from the pressure of the atmosphere to that required.

2nd. The work expended in propelling the air out of the cylinder in which it has been compressed.

Air is a body eminently elastic—that is to say, that whatever may be the compression to which it has been submitted, it will always expand again to its original volume when the compressing force is removed. During its return to its original pressure it gives out again all the work expended in compressing it. It might, therefore, be thought that machines worked by compressed air are able to give out again all the work that the air required for its compression. This would be so if there did not occur during the compression of the air several remarkable phenomena, to which attention is now drawn.

Air when compressed becomes considerably heated, but the heat produced disappears very rapidly, even when no cooling apparatus is employed. If the conducting pipes are of a certain length the temperature of the air passing out of them will exceed very little that of the external air. M. Develliz (Report, p. 16) has mentioned this rapid disappearance of the heat at the Mont Cenis works; and it was also ascertained at the Scot Lane Collieries. If the air remained at the same temperature during compression, its tension would increase according to Mariotte's law; but its heating tends to increase this tension more rapidly, so that in order to obtain a given volume of air at a given tension, it is necessary to compress it to a greater tension. Hence so much loss of work.

When the cool, compressed air is reduced by expansion to the atmospheric pressure, an extreme coldness is produced, which diminishes its volume. The expansion, therefore, is not according to Mariotte's law. Hence another loss of work.

The production of cold causes the freezing up of the machinery when the expansion takes place unless the air is perfectly dry, which is practically impossible; it always contains vapour, the condensation of which covers the sides of the engine with ice and stops the machinery.

The intensity of the cold increases with the tension of the air and the amount of expansion, consequently at Scot's Lane and Haigh Collieries the use of air compressed to 8 or 9 atmospheres has of necessity been abandoned.

Even when the machines work at full pressure throughout, the expansion of the air during its discharge causes the freezing of the vapour. The machines which work the main shaft of the hydraulic compressors at Bardonniche, are constructed to work with three-fifths expansion (M. Devilliz, Report, p. 92), but they can also work at full pressure. In the first case it has been found necessary to warm the cylinder to avoid the production of ice; in the second, the lowering of the temperature is considerable, but no inconvenience arises.

It is useless to expect, therefore, to obtain from the air more than a portion of the work expended in compressing it. The proportion will be greater according as the degree of expansion is increased.

But where should be the limit? At Mont Cenis three-fifths of expansion causes inconveniences, which can only be avoided by the use of heaters. M. Devilliz (p. 129) believes that it is quite possible to work the expansion up to double the original volume. Possibly this could be done up to 3 or 4 atmospheres, but not to 8 or 9. However that may be, the apparatus for compressed air, erected at Sars-Longchamps, has been calculated to do the work without expansion. But the underground machinery has been arranged in such a manner that the entrance of the compressed air can be cut off at will when the piston has passed one half its stroke.

The employment of expansion has an immense importance in relation to useful effect in machines worked by air. This importance can be ascertained by an examination of the figures of the following table, in which are given the quantities of work necessary to compress from 1 to 7 atmospheres effective, a litre of air taken at the atmospheric pressure. These calculations have been made without taking into consideration the loss of work which results from the heating of the air in its compression, and from the cooling in the cylinders when expansion is used.

TABLE No. 1.

	Work Expended.			Work Returned.			
				At Full Pressure.		At Half Cut-off.	
Atmospheric Pressure Effective.	To Produce the Pressure.	To Expel from the Cylinder.	Total.	Kilm.	Useful Effect.	Kilm.	Useful Effect.
	Kilm.	Kilm.	Kilm.				
1	2·583	5·167	7·750	5·167	0·66	7·750	1·00
1½	4·650	6·200	10·850	6·200	0·57	9·804	0·90
2	6·889	6·889	13·778	6·889	0·50	11·191	0·81
2½	9·225	7·390	16·615	7·390	0·44	12 166	0·73
3	11·620	7·750	19·370	7·750	0·40	12·917	0·66
3½	14·251	8·030	22·281	8·030	0·36	13·469	0·60
4	16·536	8·268	24·804	8·268	0·33	13·952	0·55
4½	19·018	8·463	27·481	8·463	0·30	14·341	0·52
5	21·522	8·609	30·131	8·609	0·28	14·605	0·48
5½	24·026	8·747	32·773	8·747	0·26	14·907	0·45
6	26·573	8·855	35·428	8·855	0·25	15·088	0·42
6½	29·077	8·944	38·021	8·944	0·23	15·312	0·40
7	31·650	9·043	40·693	9·043	0·22	15·493	0·37

It will be seen by examining this table that the useful effect that can be obtained from a litre of compressed atmospheric air increases considerably when expansion is used (even when it is not carried far into effect), and diminishes with the pressure, but in a less degree with expansion than with full pressure.

From these calculations the following conclusions can be drawn: "*having regard to the useful effect it is advisable to employ air at the lowest possible pressure.*"

Another very important point to consider is that of the conducting pipes: in order to examine into this let the particular case of the Sars-Longchamps Company be considered. The above table shows that it is necessary to produce at the head of the incline plane an actual power of 1·404 kilogrammetres per second, if we suppose the machine in the interior of the mine to give out only 50 per cent. useful effect, then to obtain 1,404 kilogrammetres of actual effect it will be necessary to expend theoretically 2,808 kilogrammetres, and this work will require the expenditure of compressed air as follows:—

TABLE No. 2.

Pressure Effective.	At Full Pressure.	Expansion at Double the original Volume.
	Metres.	Metres.
1	0·273000	0·188000
1½	0·181000	0·115000
2	0·136000	0·083300
2½	0·108000	0·065700
3	0·090500	0·054200
3½	0·077500	0·046200
4	0·068000	0·040200
4½	0·060000	0·035600
5	0·054000	0·032000
5½	0·050000	0·029000
6	0·045200	0·026500
6½	0·042000	0·024400
7	0·039000	0·022600

The volume of compressed air expended to produce a given effect diminishes proportionably to the increase of the pressure, if full pressure only is employed; it diminishes a little more rapidly still if expansion is used. The result of the experiments made by order of the Sardinian Government as to the resistance of air in pipes shows that the loss of pressure due to the friction of air in the conducting pipes is almost in direct ratio to the squares of the velocity, in direct ratio to the length, and in inverse ratio to the diameter of the pipes. This law, already admitted by M. D'Aubuisson, has been verified in the works of the Mont Cenis Tunnel, by M. Devilliz (Report, pp. 54 to 59).

The following table is a resumé of the results of the experiments made by the Commissioners of the Sardinian Government (Revue Universelle de Liége, Vol. IV.):—

TABLE No. 3.

Length of Pipes.	Diameter of Pipes.					
1,000 Metres.	0·10	0·15	0·20	0·25	0·30	0·35
Velocity at Entrance of Pipes.	Loss of Pressure in Millimetres of Mercury.					
1 Metre.	6	4	3	3	2	2
2 „	26	18	13	11	9	8
3 „	62	42	31	25	21	18
4 „	108	72	54	44	36	31
5 „	167	112	84	67	56	48
6 „	233	156	117	94	78	67

The volume of air employed to obtain a desired effect is, as has been shown, in the inverse ratio of the pressure, hence it results that for an equal diameter of pipe the velocities which the air will attain will also be in the inverse ratio of the pressure. Consequently the loss arising from the friction will increase in the inverse ratio of the squares of the pressures; that is, it will be 49 times greater at 1 atmosphere than at 7 atmospheres. Whatever may be the pressure, to have only the same loss by friction the section of the pipes ought to be in inverse ratio of the square of the pressure, and the diameter in the inverse ratio of the pressure. If at 7 atmospheres pipes of 0·10 metres diameter are used, it will be necessary at 6 atmospheres to use pipes 0·20 metres diameter, at 5 atmospheres of 0·30 metres diameter, at 4 atmospheres of 0·40 metres diameter, at 3 atmospheres of 0·50 metres diameter, at 2 atmospheres of 0·60 metres diameter, and at 1 atmosphere of 0·70 metres diameter.

In case of using expansion, the volume of air expended being less than at full pressure, it follows that for a given section there is a diminution of friction; this allows of a diminution in the diameter of the pipes, if it is desired not to vary the resistance.

The following table will show how the loss of pressure, the area, and diameter of pipes vary for the same volumes and pressures given in Table 2:—

TABLE No. 4.

Pressures Effective.	Losses for same Section of Pipes.		Sections for same Resistances.	
	At Full Pressure.	With Expansion Double the original Volume.	At Full Pressure.	With Expansion Double the original Volume.
1	49000	23383	7000	4820
$1\frac{1}{2}$	21777	8798	4641	2948
2	12250	4594	3487	2136
$2\frac{1}{2}$	7840	2901	2767	1684
3	5444	1949	2320	1390
$3\frac{1}{2}$	4000	1420	1987	1182
4	3062	1069	1743	1030
$4\frac{1}{2}$	2414	835	1551	912
5	1960	688	1385	820
$5\frac{1}{2}$	1619	544	1282	743
6	1361	467	1158	680
$6\frac{1}{2}$	1159	391	1070	626
7	1000	335	1000	579

Such are the considerations on which the "Societé de Sars-Longchamps" based the determinations for the power, and the dimensions of the apparatus for the compressed air, and the diameter of the conducting pipes.

COMPRESSING ENGINE.

The compressing engine has been constructed by the "Societé des Ateliers de Haine-Saint-Pierre," from the designs of M. Chenard, mechanical engineer. The principal condition imposed on the construction was to furnish a machine capable of supplying 5·300 cubic metres of air compressed to $3\frac{1}{2}$ atmospheres effective, with a maximum velocity of piston of 1·50 metres per second, the steam being at $2\frac{3}{4}$ effective atmospheres in the boiler, cut off so as to give an expansion of four times the original volume.

The volume of 5·300 cubic metres of air pressed to $3\frac{1}{2}$ defective atmospheres represents an accumulated work of 531,401 kilogrammetres per minute, or 8,856 kilogrammetres per second. The machine has, therefore, a practical power of $\frac{8,856}{75} = 118$ horse-power.

It was at first the intention to arrange this engine like those inspected in the English mines, that is to say, to place the compressing cylinder behind the steam cylinder and to attach the two pistons to the same rod; but this arrangement, which causes no inconvenience to the English machines, where the steam works at full pressure during the whole stroke, and where the power is far from reaching that of 118 horses, would have presented here a serious inconvenience, resulting from the great differences between the power expended and that absorbed in a given instant of time, for at the commencement of the stroke the pressure of the steam would be at its maximum, and the resistance of the air at its minimum, whilst at the end the expanded steam would have to overcome the resistance of $3\frac{1}{2}$ atmospheres in the compressing cylinder; this would only have been partly overcome by employing a fly-wheel, the weight of which for a diameter of 5 or 6 metres should have exceeded 60,000 kilos. Such a mass, besides considerably augmenting the price of the machine, would have caused a considerable loss of work due to the friction on the bearings of the shaft.

The difficulty has been most happily overcome by M. Chenard, who decided to work the compressor from a crank placed at one end of a shaft, worked by a crank from the steam cylinder attached to the other end, and to arrange the two cranks so that the moment of the greatest power corresponded to that of the greatest resistance. This arrangement has permitted the attainment of a regular movement of the engine with a fly-wheel of 5·50 metres diameter, of which the rim only weighs 3,645 kilos.

The cranks are at an angle of 72°.

The steam piston is 0·90 metres diameter, and 1·50 metres length of stroke. The expansion is produced by the system of valves of M. Farcot.

The compressing piston is 0·60 metres diameter and 1·5 metres length of stroke. If all loss and injurious spaces could be avoided, it would compress, at the velocity of 1·50 metres per second, a volume of $\frac{(0{\cdot}785 \times 0{\cdot}60^2 \times 1{\cdot}50)\ 60}{4{\cdot}5} = 5{\cdot}655$ cubic metres of air at $3\frac{1}{2}$ atmospheres effective.

The area of the injurious spaces has been reduced as low as possible; nevertheless, it amounts to 0·007950 cubic metres at the end of each stroke, this space is filled with air at $3\frac{1}{2}$ atmospheres effective, which expands when the piston commences its return stroke. The suction commences as soon as the air has reached the volume of $0{\cdot}007950 \times 4{\cdot}5 = 0{\cdot}035775$ cubic metres, *i.e.*, when the piston has travelled a distance of $\frac{0{\cdot}035775 \times 0{\cdot}007950}{0{\cdot}785 \times 0{\cdot}60^2} = 0{\cdot}098$ metres, the useful stroke is then really only $1{\cdot}50$ metres $- \; 0{\cdot}098 = 1{\cdot}402$ metres, and the volume realized per minute is $\frac{(0{\cdot}785 \times 0{\cdot}60^2 \times 1{\cdot}402)\,60}{4{\cdot}5} = 5{\cdot}284$ metres, supposing there is no loss of air through the valves and piston. It will be seen further on that these losses are insignificant.

The suction and delivery of the air in the compressing cylinder is accomplished by clack valves of India-rubber of 0·03 metres thick resting on grates; the openings of the grates are 14 for the suction and 9 for the delivery; the first are 0·07 metres long and 0·025 metres wide, the second are 0·10 metres long and 0·025 metres wide.

The compressing cylinder is immersed in a bath, the water of which is being constantly renewed. This water is drawn from the foundation of the machine by a double-acting pump, worked by a lever attached to a rod behind the steam piston; it is raised into a cistern of sheet iron at 2·50 metres above the floor, and flows from this receiver into the lower part of the bath to cool it, by a pipe fitted with a regulating tap. The hot water passes out by an overflow pipe at the higher part of the bath, and flows into the receiver of the feed pumps for the steam boilers.

All the joints in the cylinder are of India-rubber of 0·05 metres to 0·10 metres in thickness. Doors are constructed in the sides of the bath to afford means of examining the packing and the piston.

The apparatus differs in two points from those seen in England. The delivery takes place through valves of India-rubber, instead of valves of bronze or iron; the piston-rod passes constantly through water, and does not heat much; whilst at the collieries of Scot Lane and Wigan the bath only envelopes the body of the cylinder, the ends of which are clear and the piston-rod remains dry, thus it heats and rapidly destroys the packing.

The compressed air passes from the cylinder by a pipe 0·20 metres in diameter into a receiver of plate iron 1·20 metres diameter and 7·40 metres long. This receiver is placed below the floor, and is fitted up with a waste cock, a mercurial gauge, thermometer, safety-valve, and a valve to place the receiver in communication with the mine. The compressing engine commenced working in the early part of February, 1865; several experiments have been made to observe the phenomena which take place during the compression of the air, but these have not yet been carried out with sufficient exactness to be spoken of in this treatise.

CONDUCTING PIPES.

The compressed air is delivered into the mine by a main pipe of 0·12 metres diameter and 274 metres long, of which each piece is 2·50 metres long and weighs 132 kilogrammetres; at a depth of 230 this pipe is divided into two branches formed of pipes of 0·085 metres diameter and 2·0 metres in length, and weighing 74 kilogrammetres. One of these branches is actually at work; it is 863 metres in length, and is placed in an air-way partly level and partly inclined. The engine is fixed at 351 metres below the level of the compressing machine; the second branch will be 476 metres in length, and will descend like the first 351 metres in depth.

All these pipes are of cast iron, and are fastened by flanges and bolts, with weazes of India-rubber of 0·005 metres thick. The principal column is supported in the shaft by 9 lug pipes resting on two pieces of wood 0·15 metres square, built into the masonry. The pipes of 0·085 metres are simply placed on the floor of the galleries, they are shorter than those of the main pipes, so as to facilitate the carriage and placement in the smaller galleries; in some places, where the floor is subject to heaving, pipes with copper ends are placed at certain distances, which allow of the pipes yielding a little.

All the pipes are tested in the first instance to a hydraulic pressure of 12 atmospheres. The flanges are turned, and 3 small grooves of triangular section, called "grains d'orge," are arranged, which are for the purpose of increasing the resistance of the India-rubber to the force of the air.

The volume of air which the compressing machine can supply being 5·284 metres per minute, the velocity of the current in the main pipe will be per second $\frac{5{\cdot}284 \text{ metres}}{60 \times 0{\cdot}785 \times {\cdot}12^2} = 7{\cdot}787$ metres.

The machine erected at the end of the branch pipe of 863 metres, and that which will be afterwards erected at the end of the branch pipe of 476 metres, being calculated to produce the same work, will absorb the same quantity of air, the velocity will therefore be $\frac{5{\cdot}284 \text{ metres}}{2 \times 60 \times 0{\cdot}785 \times 0{\cdot}085^2}$ $= 7{\cdot}760$ metres.

It has been noted above that the loss which the air undergoes by its movement in the pipes is independent of pressure and is in the inverse ratio of diameter and the direct ratio of the length and of the squares of the pressure. These laws permit, by means of the results of experiments given in Table III., a calculation of the loss of pressure which will arise when the whole air that the engine can produce is made to pass through the pipes.

The loss in the main pipe, 0·12 metres, of which the entire length is 274 metres, may be thus considered. In Table III., in a length of 1000 metres, a diameter of 0·10, and a velocity of 6 metres, the loss reaches 0·233 metres of mercury. For a pipe 274 metres long, 0·12 metres diameter, and a velocity of 7·787 metres, the loss will be

$$\frac{\cdot 0233 \times 274 \times 0{\cdot}10 \times 7{\cdot}787^2}{1000 \times 0{\cdot}12 \times 6^2} = 0{\cdot}0896 \text{ metres.}$$

The pressure of the air at the bottom of the main pipe, at 230 metres deep, will therefore be $(3{\cdot}5 \times 0{\cdot}76) = 0{\cdot}0896 = 2{\cdot}57$ metres of mercury or 3·38 atmospheres.

The loss of pressure at the end of the pipe of 863 metres is found to =

$$\frac{0{\cdot}233 \times 863 \times 0{\cdot}10 \times 7{\cdot}76^2}{1000 \times \cdot 085 \times 6^2} = 0{\cdot}395 \text{ metres.}$$

The total pressure at the extremity farthest from the compressing machine will be $(3{\cdot}5 \times 0{\cdot}76) - 0{\cdot}0896 - 0{\cdot}395 = 2{\cdot}175$ metres of mercury or 2·86 atmospheres, and the loss from $3{\cdot}50 - 2{\cdot}86$ is 0·64 atmospheres.

But the loss is decreased by the increase of the pressure which results from the weight of the column of air itself, according to the calculations made by M. Devilliz (Report, p. 127) The weight of a column of 500 metres in height of air compressed to $3\frac{1}{2}$ atmospheres effect is equal to that of a height of mercury of 0·154 metres. The difference of level at Sars-Longchamps is 351 metres. This column will be equal to $\frac{351 \times 0{\cdot}154}{500} = 0{\cdot}108$ metres; the effective pressure at the end of the pipe will therefore be $2{\cdot}175 + 0{\cdot}108 = 2{\cdot}283$ metres of mercury or 3 atmospheres.

At that pressure 5·300 cubic metres of compressed air produced on the surface contains 461,974 kilogrammetres, of which 184,837 only in work stored up can be restored by working at full pressure, whilst if it expanded to double the original volume, 308,070 kilogrammetres would be obtained.

In the first case, 118 horse-power expended on the surface only yields in the mine 41 horse-power, and in the second case 68·40.

MACHINES IN THE INTERIOR OF THE MINE.

Only one engine has yet been erected at the point A (Plate XXXIII.) in the works of the Sars-Longchamps Company, at the top of one of the dip inclines, which is being driven in the Caroline seam. Two other engines of this kind will be erected in a few months; one at the point B will be used to win out to the dip the seams "*Huit paumes*," "*Pré*," and "*Marie*;" the third at the point C will work the "*Grand Vein*" and the "*Sehu*" seam.

The machines A and B have the same dimensions, but the first will only work at full pressure, whilst the second will work expansively up to double the original volume. They are constructed identically like steam engines, except the ports of admission and discharge, to which are given much greater area than those of a steam engine of the same dimensions and working at the same pressure. The velocities of discharge of gases are in inverse ratio of their densities, and the density of air at 15° c., compressed to 3 atmospheres, is to that of steam of the same pressure as 5·172 : 2·119.

In order that there may be no more resistance to the entry and discharge of the air than there is in a well-proportioned steam engine, the area of the ports of the machines A and B are increased in that proportion.

These two machines are calculated to draw at a velocity of 1·33 metres per second (on an incline plane of 28°) three mine wagons of 990 kilogrammetres of coal, each empty wagon weighing 160 kilogrammetres.

The haulage is effected by ropes which roll on a drum of 0·60 metres in diameter. Movement is given to this drum through a pinion and a spur wheel, the diameters of which are in the ratio of 1 to 2. The piston is 0·30 diameter, and 0·60 length of stroke; it is made like the piston of a steam engine, the rings being of cast iron.

The compressed air, before reaching the cylinder, passes into a receiver, 1·20 metres in length, and 0·60 metres in diameter. This receiver is required to receive the water drawn along by the air, and is furnished with an escape cock and a mercurial gauge.

The machine B will be arranged so that the air will work with expansion up to double its original volume, but the cut-off will be able to be instantly suppressed.

The machine C will be similar; this is an old steam engine which was used some years ago at one of the dip inclines. It has a cylinder of 0·25 metres in diameter, and 0·50 metres length of stroke; the diameters of the pinion and spur wheels are in the ratio of 1 to 3; the ropes are rolled on a drum of 0·50 diameter. This last engine, the erection of which has recently been decided on, will be placed 405 metres in depth, in the workings of the No. 6 Pit. It is near this winding shaft where the compressing engine is placed, and it is down a compartment reserved at the side of the winding pit that the main pipe descends into the workings, to supply the interior machines; this main pipe will be prolonged to a depth of 405 metres, and will be placed in communication with the machine C, by pipes of 0·085 metres diameter, of which the total length will be 110 metres.

Since the different apparatus, actually erected, has been at work, *i.e.*, since the early part of February, 1865, no derangement has occurred. At the commencement some joints of the conducting pipes allowed a considerable quantity of air to escape; but in all cases it was only necessary to tighten the bolts to stop the leak; so that now, if the engines are stopped when the air is at 3½ atmospheres in the receiver and the pipes, it requires more than 10 hours to bring down the pressure to ½ atmosphere.

The working of the compressing engine is most satisfactory; the India-rubber falls, after working more than two months, are almost uninjured. The escape of the air through the piston is insignificant; this fact has been ascertained by experiment, by calculating the number of cylinders full, necessary to bring the pressure in the receiver, of which the capacity is known, from 0· to 3½ atmospheres.

The temperature of the air in the receiver never exceeds 40° c.; but the quantity of water which will be required to be used in the bath, to keep it down to this temperature, when the machine works with all its power, will be considerable; it will require, probably, at least 3 litres per second.

The machine underground works most satisfactorily; however, a very considerable heating of the cylinder takes place; this increase in the temperature is due to friction (although the cylinder is greased like a steam engine cylinder), and will disappear as soon as expansion is used.

The CHAIRMAN said, it was a very satisfactory paper. Mr. Daglish had put in plain language a great many laws and formulæ, which in mathematical works were often given in a shape which was extremely difficult to follow or understand; for gentlemen in their position had quite enough to do with the ordinary business of life, and could not afford very much time to study. As to compressed air, there was very often a great amount of mistaken confidence placed in it; they could not for a moment expect to receive in useful effect anything like what might be obtained from the ordinary steam-engine. No machine developed the full amount of power supplied to it, and this loss was at least doubled when one engine had to develope power for another engine to use. He had heard very different views expressed; but still he had never seen any experiments which could in the least controvert what he had stated. He asked Mr. Daglish to put in the form of a diagram some of those tables, which would then be more easily appreciated, and thereby add to the value of the paper. It was not customary to discuss papers much at the meeting at which they were read; but if any gentlemen would like to ask any questions, while Mr. Daglish was there, they would be very glad to hear them.

Mr. Daglish mentioned that the paper was not by him; it was simply a translation. If there was any gentleman there who could give them information on the matter, he was sure his doing so would be very pleasing to those who had taken an interest in this special power, because there were some very intricate questions connected with it, on which they wanted information.

The Chairman said, as they had not got Mr. Taylor's paper before them, and as it was understood that they should soon have an opportunity of going to the colliery and examining the machinery therein described, perhaps it would be well to postpone the discussion on Mr. Daglish's paper until they had done so, and thus take the whole question of compressed air together. If they agreed to that, they would go on with the discussion on the Counterbalancing of Engines. He would like to hear some of their views upon this question.

Mr. Bunning would like to ask if any gentleman had had any experience with engines which, as it were, counterbalanced themselves; that is to say, where the drum had no conical arrangement or balance whatever, but where the cut-off of the engine was so arranged that they could get the full steam when the cage was first lifted and the whole of the rope was down the pit, and gradually cut-off the steam as the load came to bank, and was thereby lightened. He thought it would be very interesting, and would add very greatly to the interest of the papers on the scroll drum if any gentleman who had experience in engines similarly arranged, would be kind enough to give it.

Mr. Daglish, before they left the subject, would observe that Mr. Fowler spoke in his paper of the dynamical action of winding engines, and the inertia of large masses of machinery and rope at the commencement of the lift and the momentum at the end of the lift, to equalise which effectually would require a very exaggerated scroll drum. It seemed to him that the dynamical action could be overcome more easily by a separate counterbalance chain attached to the scroll drum, the scroll drum being used solely for statical requirements. He had a diagram prepared which had been calculated to illustrate this. This combination of the two could make the action throughout pretty nearly perfect, so that a much smaller winding engine and much less power than usual would be required. He might mention that during the last fortnight or three weeks there had been some experiments made with Story's power meter, which would be ultimately laid before the Institute. It was an extremely ingenious instrument, and showed the action of the winding engine very clearly and in a very interesting way throughout the whole of the winding. The experiments were not yet in a form to lay before the Institute, but he believed he would be justified in saying there was a saving by putting on that extra counterbalance, of something like five seconds out of fourteen of the winding, and a saving of absolute power in the engine of something like seven to nine, but these experiments would be laid before them afterwards.

Mr. Bainbridge said, the power required to move a load in winding, especially where large weights were employed, must be exceedingly difficult to ascertain. He had seen a scroll drum in Nottingham which required four times the actual load to move. A perfect scroll drum, or rather one with the degree of perfection which Mr. Fowler thought would do, would require 10 or 15 tons more actual weight than the present drum and would possibly require still more than four times the load to move; the effect of putting on a counterbalance chain would be to increase very much the load upon the shaft of the lifting engine; and as that meant increased size of shafting it would be a very serious thing.

The Chairman stated that he had lately got out the weights of some flat rope rolls at present in existence, and he found that they were quite as heavy as the scroll drum. The remarks of Mr. Daglish reminded him that he thought Mr. Fowler was mistaken in calculating the power necessary to move the drum. It was a very different thing causing a body of 35 tons, or whatever weight the drum might be, to revolve, and lifting it bodily up from the bottom of the pit to the top. Mr. Fowler appeared to have treated the weight of the drum as weight to be actually lifted up the shaft. Now, the drum had simply to be turned round, and it required a very different amount of power to cause a body to revolve from what it did to lift it.

Mr. Waller remarked that the diagrams on the wall indicated the combined defects of both engine and ropes, and the discussion again assumed perfection of machinery. While considering the balancing of the winding engine, they ought to direct the discussion to two points; first, balancing the engine; and second, balancing the ropes. On the first point, it would be found that few, if any, winding engines were balanced in their parts, or in the action of the steam at either end of the cylinder. On the second point, though it might be theoretically easy to calculate and make a scroll drum which should be in perfect balance when at rest, at any point in the length of the rope, such a drum would be open to the same objection of not being in balance when in motion, owing to the difference in the velocity of one rope and that of the other, and the consequently increasing *vis vivâ* as the cage came to the surface, hence the two would be in actual balance for a moment only. Now, when this difference is ascertained and worked out upon a rope, where the average speed is about thirty miles per hour, it will be found to be very considerable, and would astonish the advocates of the scroll drum. Then, to put a fixed weight upon a chain or rope as counterpoise, would be, as Mr. Bainbridge expressed it, to add considerably to the load; but to carry this weight out to the point suggested, to load the engine until the momentum was lost, as soon as the steam was shut off, would be to multiply the cost of working. In the question under consideration, it is only fair that the engine and drum should each bear the blame of its own defects.

The discussion then terminated.

PROCEEDINGS.

JOINT MEETING WITH THE INSTITUTION OF ENGINEERS AND SHIP BUILDERS IN SCOTLAND, AND THE SOUTH LANCASHIRE AND CHESHIRE COAL ASSOCIATION, JULY 2ND, 1872, IN THE WOOD MEMORIAL HALL.

MR. ALDERMAN GREGSON, THE MAYOR OF NEWCASTLE, IN THE CHAIR.

THE MAYOR—Ladies and Gentlemen, we are here to-day on a very important occasion, to receive the Mining and Mechanical Engineers and the Coal Owners of both the North and the South. We are also here to inaugurate this splendid building, erected to the memory of one of England's worthies, the late Nicholas Wood, a gentleman to whose energy and untiring zeal in practical and scientific pursuits the country is deeply indebted. We are here also to give a cordial welcome to the Members of the Institution of Engineers and Shipbuilders in Scotland, and to the Members of the South Lancashire and Cheshire Coal Association. The hospitality of these gentlemen is well known to many of the professional gentlemen of this district who had the good fortune to be present at the magnificent entertainments given to the members of the Newcastle Institute at Manchester and at Glasgow some years back; and the papers read at these meetings, and those printed in the Transactions of the Institute, bear record to their scientific attainments. In the name of the inhabitants of Newcastle I bid them welcome to the canny town, and trust that they will enjoy their visit.

With regard to this building, I am convinced that no more appropriate means could have been conceived for perpetuating the exertions of Mr. Wood in the cause of science than erecting this structue to his memory and devoting it to scientific pursuits; and I trust that it will in future be the arena in which each successive President will add his quota of assistance to the great work of scientific progress so ably furthered by Mr. Wood. I cannot quit this subject without alluding to the very great and untiring labours of Mr. Boyd, your present President, in promoting the establishment of a College in Newcastle. This gentleman, in connection with the Dean of Durham, the Rev. W. C. Lake, a man of large, liberal, and comprehensive views, and other leading gentlemen, have at length succeeded in procuring this boon to the district, and in bringing to a successful issue the work contemplated by Mr. Wood, in his first address to the Institute, in 1852.

With these few observations I have great pleasure in declaring that the inauguration of the building is complete.

I have also great pleasure in most cordially thanking our visitors who have honoured us to-day with their presence, and I trust that their remembrance of their Newcastle visit will be as pleasant as that which we have of the visits we made to Manchester and Glasgow. In conclusion, I have great pleasure in vacating the chair, in favour of Dr. Rankine, of Glasgow.

Dr. Rankine stated, that it was a subject of great regret to him, though, at the same time, one of satisfaction and gratification, that he took the chair on this occasion. It was to have been taken as previous announcements have shown you by the distinguished President of the Institute of Engineers in Scotland, Mr. R. Bruce Bell; and he lamented sincerely that the state of his health has made it absolutely necessary that he should be absent on this occasion and remain in a southern climate. He would not detain them longer but would ask Mr. Boyd to read the Inaugural Address.

INAUGURAL ADDRESS.

By Mr. E. F. BOYD, President of the Institute.

Ladies, Members of the Institute, Friends, Gentlemen, and Strangers—During the three years in which it has been your pleasure to honour me with the position of your President, I have had many and various instances of conferring and debating with you on subjects of great interest and usefulness to your Society, under circumstances of considerable anxiety and concern for its welfare, and upon matters though not immediately a part of its nature, yet growing out of it, and in the success or failure of which the prestige of your Institute was ultimately concerned. I have also in the same capacity had cause to be made earnestly alive to its credit and standing in the eyes of other societies, whilst taking advantage of the polite and generous invitations to other centres of arts and sciences. Yet, I may without hesitation avow, that never during my intimate connection with, and earnest endeavours in its behalf, have I been called upon to introduce to your notice any subject with which its welfare is more deeply concerned, and possibly, its future more earnestly involved, than the cause of our meeting on this day, viz., the inauguration of the "Wood Memorial Hall."

The topic we have to talk over is one of a calm, conciliating, and complimentary character, perpetuating the memory of pleasing by-gone associations, and I am sure no one whom I have the pleasure to address, will find any opinion of his ruffled by any counter sentiment which I may have to offer.

What interests a large family more than the nature and character of its home? In what could the objects and intentions of the establishment of your society be more entirely answered, than in possessing a centre of action, a place for the interchange of the thoughts, observations, and experiences of each of its members, at which the originations of one may be checked, guided, and counselled by the suggestions and criticism of another, as well as an almost sacred place of deposit for all the collected plans, documents, and instruments which may have hitherto, or may hereafter flow from and be collected by such a Society?

If your own want of such a centre of action in the increased and increasing value of your Society had not prompted the erection of such an edifice, you have the authority of all example before you. Each of the renowned kingdoms of the world, as it came to cultivate the arts and sciences, was in its turn possessed with the advantage and even necessity of a "Hall" or place of public resort. We believe it to have been the case with Thebes and Babylon, as well as Nineveh. Athens was not without her "Areopagus" or place where her citizens could hear or "tell of some new thing;" and Rome was not without her "Forum;" and the latter never made a permanent settlement in any part of her wide-spread territory, unless she provided there too a place of public resort and communication; so in our own times and country, almost every city of importance has its Town Hall or its Literary Institute.

You need not, in my opinion, seek for any palliation or excuse, then, for the erection of such an edifice, nor for the costly manner in which you have thought proper to adorn its structure. The several purposes and uses in which it will become an accessory to the intention of the establishment of your Institute, are evident and obvious.

Prior to your existence as an Institute, scarcely one standard treatise on the Coal Trade could be referred to, either as a model for the training of "noviciates" in your engrossing and widely influential profession, nor for consultation in cases of difficulty and danger; and now, your twenty volumes form a reference text, an exposition, such as I know you seek in vain for, in any Encyclopædia, any chemical, or mechanical, or commercial dictionary to yield to the enquirer the information therein contained.

If heat is power, and heat is best and most easily obtained as yet from coal, then you hold a charge of great responsibility in your hands, for the economical and safe working of coal must always be a matter of vital interest, not only to all of us here assembled, but to the world at large. It needs very little consideration to come to a conclusion, under the present extended ramifications of our underground operations, that the duration of the supply of our mineral fuel depends largely on the application of scientific improvements to the ventilation and advantageous access to our extensive coal-mines. When we have exhausted those portions lying under the dry land, we must endeavour to make that which lies under the sea yield up its treasure; when we have cropped and culled all the thick and richer seams, we must invent schemes to bring those which are thinner and poorer within the bounds of utilization; and where manual labour is incapable of application to such production, we must endeavour to make machinery and science prolong the duration of England's wealth and happiness, even beyond the period defined by the interesting report of the Royal Commission, recently published on this subject.

It would appear then, that you cannot give too much attention to this important subject, you cannot give those employed in its studies too many facilities for the cultivation and expansion of an occupation of so wide-spread an influence, and one which requires in its professional emergencies of difficulty, danger, and difference of opinion, a union in one mind of the concentrated intelligence of so many other professions; from the handler of the pick-axe and the trowel, to the wielder of the most delicate or most powerful appliances of machinery, from the intricate experiences of a veterinary surgeon, to the nice distinction of legal phraseology or the delicate results of chemical manipulation; and to this must be added the almost boundless responsibility of a manager of collieries who, frequently alone, is suddenly called upon to form an opinion in cases of extreme danger and difficulty, involving the lives of many in whom he is intimately interested, and the safety of property of incalculable value, and to act upon such opinion with promptness and decision; the catastrophies of Hartley, Page Bank, and Lundhill Collieries afford apt illustrations of the magnitude of these responsibilities.

In a speech made by the Premier (Mr. Gladstone) at the annual dinner of the Civil Engineers of England, at which, in compliment to yours as a sister Society, I was, as your President, invited, in endeavouring to define the high standard to which Civil Engineering in England had reached, he remarked, "This is an age, gentlemen, which appears to have "been given in a special degree to you. During our own time, over which "our memory reaches, it has arrived at gigantic development. There is "but one personage, who, if she were gifted with a mouth and a tongue, "would raise her voice against you, and that is your ancient mother earth. "Whatever benefits you have conferred upon human kind, on her you "have inflicted cruel suffering. The guilt of parricide, Mr. President "and gentlemen, is great, but your iniquities are greater still; for you "have mutilated and mangled your first parent without putting an end "to her existence. And when is this to end? You have already covered "the civilized portion of the world, and you will rapidly pierce the un-"civilized. The cataracts of the Nile are no longer secure, I believe "that the next step will be a railroad across the great desert of Africa; "underground as well as aboveground you will be compelled to employ "yourselves, and when you have dealt sufficiently with the bowels of "the earth, there will remain to you the regions of the air. No doubt "a period will arrive when, like Alexander, sighing for new worlds to "conquer, you will begin to think of the other members of the planetary "system—but I do not think that will be in our day—for the present I "think you have before you sufficient occupation."

Our Society may, like the Civil Engineers, content itself with the idea, that even if we have not other worlds to conquer and deeper seams to explore, the day of exhaustion of Britain's resources under present explorations will not appear in our time.

What immense value and interest the papers to be read and the discussions to be held in such a Hall must be to the improvement of the minds of the junior members of your profession. Within a very few years the term of apprenticeship was confined strictly to the works under the charge of the gentleman to whom a young man was apprenticed, and if the experience thus attained was not supplemented by a term of collegiate study the young aspirant necessarily laboured under disadvantages; for there must be a certain debateable line beyond which the defectively educated cannot expect to progress. Let us hope that it is not presumptive now to believe that the advantages of a collegiate education, recently, by great united effort, brought within the district of the Tyne, and the experiences and discussions which occur periodically within these walls, may jointly be the means of removing the disadvantages hitherto experienced, by breaking the line of demarcation and by erecting new landmarks, thus giving our younger members the privilege of entering on the arena at once with those of longer probation in the various intricacies of their profession; and by making his starting point at a higher level than heretofore, not only place the acquisition of University honours and diplomas within his reach, but also tend to elevate the title and character of the Association generally, and raise to the highest standard the tone of the profession; each one in his station ardently applying himself to the acquirement of the rich stores of knowledge placed within his grasp, and following the laudable example of our first President, by generously devoting his accumulated fund of wisdom to the advancement of his profession, the encouragement and direction of those around him, and in founding institutions of a similar nature as our own for the good of his species in this and future generations.

In further encouragement of the youthful amongst us, and in order to induce them to take an interest in this building and the purposes to which it may be used, let me remind them that, although they may observe how very much of the work is accomplished by a few only of the members, yet each may derive individual benefit by interesting himself in its proceedings, and in a hundred ways add to its efficiency; the intention of our Society being to show a sort of corporate life amongst us, ready to feel sympathy, and to communicate energy, "to assist the struggles of the weak and to applaud the success of the strong" in the daily duty of exciting ingenuity and stimulating discovery.

It will be well to bear in mind that, although the nature of the engrossing and busy occupation of a mining engineer would seem, to a certain extent, to interfere with the attainment of a high standard of literary acquirement, it is not from the quarters that the most brilliant contributions to human advancement have been always made; it was not from this class that Stephenson, Watt, Burns, Chantrey, or Elihu Burrett rose; indeed, in the case of the latter, a remark was judiciously made, that if he had not been forced to labour, he would, in all probability, have devoted himself so incessantly to his books that he would have ruined his health and been carried to a premature grave; and thus is drawn the conclusion, that work may not only be no impediment, but even an assistance to intense literary labour, and that genius and the results of well directed industry are confined to no order of our species.

If then these are but few of the advantages and privileges which I have endeavoured (however meagrely) to point out as those to which your Hall may be made applicable, whose name could you, in the exercise of the kindly spirit of giving honour to whom honour is due, more correctly attach to your home of resort and council, than that of the man whose mind first suggested the idea of the foundation of your Institute, and to whose memory but his could you more appropriately dedicate it? His large and generous heart was uneasy in so frequently witnessing the dreadful calamities consequent upon accidents in mines, and a large portion of his life was devoted to the encouragement, development, and perfecting the Institution which became, towards the latter end of his useful career, his "favourite professional child." He would if living, have rejoiced to see the day which I am sure will prove a memorable epoch in the history of your Institute.

Permit me to bring before you a few of the chief incidents of his life. They have been very neatly and elegantly detailed by your late Secretary, Mr. Doubleday, in a memoir of Mr. Wood in the 15th volume of your Transactions; and, though reading it at length might by some be considered tedious, yet a few of the leading points in the eventful life of him we are met to honour may be well brought more immediately on this occasion to our recollection—his birth, in 1795, at Sourmires, in the parish of Ryton, on the south side of the river Tyne—his first schoolmaster, Mr. Craigie, of Crawcrook; and his apprenticeship at Killingworth Colliery, through the influence of Sir Thomas Liddell, of Ravensworth. At Killingworth Colliery the young man was thrown into the society of one who exercised a considerable influence over his future life; and whose own arduous and successful career his young companion unquestionably assisted to bring to a fortunate issue. This was George Stephenson, then himself a young man whose persevering ingenuity had already begun to attract attention, notably in the case of the pit which was sinking at Killingworth being flooded with water, and which he, being the engineman, offered to clear "If they would let him so increase the powers of the pumping engine, by changing the nozzles, as to cause it to command the feeder." This was done, and the pit was completed; at the same time he was made directing engineer of Killingworth High Pit. In young Nicholas Wood, Stephenson would find exactly the coadjutor he wanted. His young companion was endowed with imperturbable good temper, a docile disposition, great power of application, and perseverance under difficulty scarcely inferior to his own. Young Wood became his confidant, the depository of his plans and schemes, and his assistant in that series of experiments without which the locomotive engine might yet have remained unknown. Mr. Wood also assisted George Stephenson in his next interesting invention, viz., that of the safety-lamp, inasmuch as he made the first drawing, while Mr. Hogg, the tin-worker in the Side, made the metal part, and the Northern Glass Company, the glass. After great consideration and study, and numerous experiments, the "Geordie" lamp was produced in such a condition as to be capable of being burnt with comparative safety in an explosive atmosphere. Young Wood was one of those who had courage to attend his friend and witness the testing of the lamp at a blower in Killingworth Colliery—a perilous experiment, but one readily fronted by men enthusiastic in pursuing scientific improvements and inventions of whatever nature. In 1815 the lamp was exhibited at the Literary and Philosophical Society of Newcastle, at that time in the Bigg Market, young Wood adding to George Stephenson's explanations many proofs and details elucidating its peculiarities. Sir H. Davy's lamp has, in some cases, superseded Stephenson's, which proves nothing more than that an original inventor rarely brings his own idea to entire perfection. The Marquis of Worcester, Savory, and Newcomen had the notion of the steam engine before Watt developed it. However, the safety-lamp, as invented and matured by Stephenson, is still in use at Killingworth Colliery, under the suggestive title of the "Geordie" lamp. Mr. Wood warmly advocated the claims of Stephenson in the controversy of these simultaneous efforts of Davy and Stephenson, for the latter, like many eminent men, was deficient in the art of expressing his thoughts clearly either in speech or writing.

Of Stephenson's appreciation of the acquirements and abilities of Mr. Wood we cannot have a better proof, than the fact that he apprenticed to him his son Robert Stephenson, who afterwards, when the eminent engineer, was not slow to acknowledge his obligation to his early instructor.

About this time the railway system began to be developed, the first projected being that between Stockton and Darlington. George Stephenson was employed upon its construction by Mr. Pease and the other promoters, and Mr. Wood accompanied his friend to Darlington.

Stephenson and Wood might then be considered the practical engineers of the day; and in 1825 the latter published a "Treatise on Railways," which, to this day, remains a standard work. In 1827 Mr. Wood gave evidence of the practicability and desirability of the then projected line of railway between Liverpool and Manchester, before the Parliamentary Committee appointed to investigate the subject. It was before this Committee that Mr. Stephenson underwent a searching examination, during which his ready wit and powerful reasoning completely overcame the opposition of his adversaries.

In 1838 the British Association held their Annual Meeting in Newcastle, and this afforded Mr. Wood an opportunity of producing his elaborate essay on the Geology of Northumberland, which forms a part of the 7th volume of the Transactions of the British Association, and of the 2nd volume of the Transactions of the Natural History Society of Northumberland and Durham.

The subject of this paper, though at that time confined to the Geology of Northumberland, was in a subsequent paper printed in the 11th volume of your Transactions, greatly enlarged upon by Mr. Wood in his endeavour to establish the connection of the Northumberland and Durham coal basins with the smaller coal-fields of Berwick and Plashetts, the coal basin of Canobie, on the borders of Scotland, and the coal-fields of Scotland generally.

In 1844 Mr. Wood removed to Hetton Hall, where he spent the remainder of his arduous and useful life.

In 1839 one of those melancholy explosions, which cause such destruction of human life, occurred at Hilda Colliery, and public attention was strongly drawn to the necessity and desirability of some system of inspection, by which the working of coal mines might be regulated, and rendered less perilous to those engaged in it. Mr. James Mather, a man of talent and considerable energy and perseverance, was one of the many members of a Committee appointed at South Shields to investigate the circumstances attending those casualities, and their report was published two years afterwards.

This drew the attention of Government, who sent down two Commissioners, Sir H. de la Beche and Dr. Playfair, and afterwards two others, Professor Phillips and Mr. Blackwell, to investigate the circumstances connected with the catastrophe, and these gentlemen advocated the necessity of some system of inspection which should be sanctioned by Government. In the necessary investigation Mr. Wood, with other leading coal owners and mining engineers, took an active and important part. In the general principle of inspection the coal trade unanimously acquiesced, and the result was the enactment of the first Inspection Act, Vic. 18 and 19th, cap. 108.

One of the earliest consequences of this combined action, on the part of the public and the Government, was to convince the leading members of the coal trade of Northumberland and Durham that some further efforts were required on their part to improve both the theoretical and practical departments of mining science; and on July 3, 1852, a meeting of coal owners and viewers of collieries was held at Newcastle, the late Mr. W. Anderson occupying the chair. This and a second meeting resulted in the formation of your Society, the North of England Institute of Mining Engineers, which is now entitled the North of England Institute of Mining and Mechanical Engineers. The Institution was formally inaugurated in August, 1852, when Mr. Wood was elected the first President; the four Vice-Presidents being Messrs. Thomas J. Taylor, T. E. Forster, W. Anderson, and E. Potter; Mr. E. Sinclair being Secretary, and myself Treasurer. The President's inaugural address was delivered on the 3rd of the following September; and the number of members enrolled during the first year was 100. The Institution has gone on steadily increasing in numbers and utility up to the present time; and although the officers were annually elected, so highly were Mr. Wood's services as President estimated by the body over which he so long presided, that he was annually chosen President by a great majority of votes, and held the office up to the day of his lamented death.

Such are a few of the principal incidents of an active and useful life; the recollection of which would, in all human probability, have succumbed, like the history of our own, to the inexorable doom of oblivion, but for the compliment you this day assemble to pay to his memory.

A monument is the erection of a subject of beauty to satisfy that honourable pride with which a high-spirited community cherishes the memory of its great men. The question may occur to some, do men like George Stephenson and Nicholas Wood, who have done so much for the generation in which they lived, require a monument of bronze or marble?

What needs my Shakespeare for his honor'd bones,
The labor of an age in piled stones?
Or that his hallow'd reliques should be hid
Under a starry pointed pyramid?
Dear Son of Memory, great heir of fame,
What need'st thou such weak witness of thy name?
Thou, in our wonder and astonishment,
Hast built thyself a life-long monument.

And, so sepulchred, in such pomp dost lie,
That kings, for such a tomb, would wish to die.

Such a pyramid I do not think the retiring temperament of our friend would have sought for, but such it is your pleasure to dedicate to his memory. He was a geologist, a mathematician, an engineer, and a practical miner, a large-hearted lover of, and an unwearied worker in, scientific pursuits, and he always had a word of encouragement for those

The following is a list of Papers read before the Institute by Mr. Nicholas Wood:—

	Vol.	Page.
1st Inaugural Address	1	13
Value of Steam Jet compared with Furnace Ventilation	1	71
Safety-lamps	1	301
Haulage of Coal Underground ... Vol. 3, p. 239	5	65
Sinking through Magnesian Limestone—Seaham and Seaton	5	117
Explosion at Lundhill	5	231
Magnetic Ironstone at Rosedale	7	85
Memoir of George and Robert Stephenson	8	33
Accident at Burradon	8	85
Explosion at Seaton Burn	8	86
Memoir of Joseph Locke	9	56
Explosion at Hetton...	9	93
Memoir of Thomas John Taylor	9	237
Inaugural Address at Birmingham	10	3
Upper and Lower Coal Beds of Durham and Northumberland	11	101
Exhibition of 1862	11	227
Coal Mining	12	149
Joint Paper by N. Wood and E. F. Boyd on the "Wash" through a portion of the Durham Coal-field ...	13	69

He also presented a set of Thorpe's Diagrams of the Yorkshire Coal-field to the Institute.

similarly employed. His influence over this Institute was powerful and beneficent, and surely your desire this day to combine his name with that Institute must be a laudable one.

Do not let me omit before closing the few words you have done me the honour so patiently to listen to, to introduce words of compliment (and in which I am sure you will each and all of you unreservedly join me) to Mr. Arch. Dunn, the architect, whom you have chosen for designing and carrying out the details of your Hall, as well as to Mr. Wyon, whose powers in the art of sculpture have so forcibly and enduringly brought to your vision the features of our friend. Science has the strongest claim to all the fealty which we, as a society, can pay; and there is happily no reason why art and science should not dwell together in amity.

In the mediæval ages they went hand in hand together, and were often excelled in by the same individual (for example the immortal Michael Angelo and Leonardo da Vinci), and it was hard to define whether sculpture, architecture, engineering, or painting shone the more brilliantly in their transcendently accomplished minds. I may be excused in quoting the elegant allusion to this union in the speech of Professor Tyndall, on behalf of the Royal and other learned Societies, when he said:—"Art and science are indeed both suitors to the same mistress, "nature; they are so in a sense and fashion which precludes the thought "of jealousy on either side; the one loves her for her beauty, the other "for her order and her truth. The dry light of the intellect, the warm "glow of the emotions, the refined exaltation of the æsthetic faculty, "are all part and parcel of human nature, and to be complete we must "be capable of enjoying them all."

It is a happy coincidence that in this same good old town of Newcastle, the two monuments of George Stephenson and Nicholas Wood should exist in such close proximity, and, if it be correct that the spirits of good men are permitted a consciousness of the acts of those from whose midst they have departed, must it not add somewhat to the encouragement of each of us on approaching this emporium of activity and industry to be assisted by the thought that these two happy spirits, once fellow-labourers in the same field, together view with satisfaction the mode in which we have chosen to perpetuate their memory and their worth?

Gentlemen, I am sure you will excuse me adverting on this occasion to another event which may be of life-long interest to your Institute, I allude to the formation of a College of Physical Science in this centre of the arts and sciences in the North of England. The establishment of such a College was earnestly desired by Mr. Wood, and it is a matter of great gratification to myself to have been your President during its inauguration, and to have been permitted to assist in the great work. In order to make you aware of this pleasure now realized, I need not dwell on the many earnest conversations concerning it which I held with my late lamented friend, Archdeacon Thorpe, one of the founders of the Durham University, or his anxious canvassing of the subject with Mr. Wood and Mr. Thos. John Taylor, and of the scheme falling through or remaining in abeyance for many years in consequence of the difficulty of parties agreeing as to the relative merits of Durham and Newcastle as the proper site; on the happy resumption of the question within the last twelve months; on the renewed appeal to the generosity of the public, by your Institute, through its council and members, and after mature deliberation, and the hearty response and co-operation on the part of the Dean and authorities of the University of Durham, all of which has happily terminated in the inauguration of such a seat of learning for the cultivation, improvement, and teaching of Mining and Physical Science, in this district, the northern centre of their practical existence.

You must please excuse the amount of pride which I cannot help feeling, when I reflect on the part (however insignificant) which I have been permitted to take in this work, which we all consider will be of the greatest assistance to our Institute, and expressing the satisfaction which will accrue to me during the few remaining years of my existence in the knowledge that the work was completed during the period in which you permitted me the honour of presiding over you.

I think we cannot be wrong in considering this matter as not only of local but of great national importance. The education of a large proportion of the youth of this district in natural philosophy must elevate the general tone of the community, and conduce to the honour and prosperity of the nation, and enable it to develope the vast industrial advantages which it possesses, and we cannot but feel that such objects and institutions ought to be made matters of national concern (of which there are numerous instances on the Continent) and not left, as heretofore, to private enterprize or the possible undulations of societies however well conducted.

Although from the nature and connection of the subject, we have nesessarily dwelt more particularly on the encouragement of the cultivation of physical science, I quite coincide with the observation of your late President, Mr. Geo. Elliot, in his inaugural address, when he remarks that all the qualifications of a gentleman are capable of being blended with the technical knowledge required for, and the anxieties incidental to, your difficult profession. Therefore let us hope that the day is not far distant when the objects and aspirations of this College we have seen so favourably commenced may not limit its teaching to Natural Philosophy and Chemistry, but may extend its professorships to the chairs of Biology, Ancient and Modern Languages, English History, Political Economy, and the Arts, and that it may continue to be so well supported, whether nationally or individually, as to allow of its having a collegiate building set apart for its sole use, comprising lecture and experimental rooms, and accommodation for resident and enrolled students, within its walls, like the older universities.

Then may I hope that there may arise in the minds of its Council of Management the admission of the principle—the indispensable principle, in my humble opinion—that all acquirements should be grounded on a religious basis. Depend upon it, there is no more fitting and genial shelter under which all sound and useful studies and ornamental accomplishments can thrive and spread—a shelter which protects them alike from the chilling and nipping blight of indifference and from the blasting breath of bigotry—tempering habits of independence and self-relying thought with profound humility for that which is supreme, and with tenderness and reverence for the conscientious convictions of others.

From my inmost heart, then, I join in the wish, which I feel sure will be entertained by all who have now this day been brought together, that this building, which we have been permitted to inaugurate to the memory of our friend, amid so many demonstrations of goodwill and concord, may become the resort of your members when they meet together to compare their experiences, and that these discussions will elicit facts, truths, and intelligence, which shall tend to extend and widen the sphere of usefulness of this Institute, and promote the original intentions of its founders by increasing security and well-being of the sons of toil, without whose aid all our science would be as nought; Finally, may Almighty God (through whom your highest intelligences are permitted to you) vouchsafe His best blessings upon the undertaking and upon every one through whose instrumentality it has risen to its present state of usefulness.

Mr. C. L. Wood—I cannot allow this opportunity to pass, without, in the name of my family and myself, publicly thanking those who organised the idea of erecting this Hall to the memory of my father, and have carried it out so well. I have to thank you for the way in which you have spoken of my father through Mr. Boyd.

The Chairman—It is now my duty to propose a vote of thanks to Mr. Boyd for the admirable Inaugural Address you have just heard. He has set forth, in the clearest manner, the advantages of such institutions as the scientific college we are now opening. He has put it in so clear a manner, that it is almost impossible to add any words of remark; but, further, he has, I am sure, given the greatest gratification to the feelings of all here present by his account of the merits of that noble man to whose honour this Hall has been dedicated—Mr. Nicholas Wood. I confess that I cannot refer to him without much emotion of a personal kind. His memory is honoured by the whole of the profession to which he belonged for his great practical skill, and his great scientific knowledge, and his indefatigable energy in devoting these to the good of his species; but I may say his personal character is a matter of not less regard. I cannot help expressing my own feelings on the subject. I was fortunate enough to know him well; he was the contemporary and personal friend of my own father. I have known him from the time that I was a boy, and I have often received from him much kindness and hospitality. You must excuse me saying this: for I cannot help expressing my own personal feelings. The body I have the honour to represent here will, I am sure, join with the North of England Institute in honouring the name of Mr. Nicholas Wood. We are all deeply indebted to his labours for our knowledge; and I may say that I feel there is something appropriate in the honour that has been done us in asking a representative of our body—the Institute of Engineers in Scotland—to take the chair just now. It is a kind of mark of this being an occasion not merely of local importance to the inhabitants of Newcastle and the North of England, but of national importance, that the representative of a body, whose home is at a distant locality, should be asked to preside. In conclusion, I will again move a cordial vote of thanks to Mr. Boyd for his Inaugural Address; and I may add this, that a great deal more might be said than he has said regarding his own share in the erection of this Institute. Mr. Boyd, I beg to express the thanks of this meeting to you for your address.

The Very Rev. the Dean of Durham said—Mr. Chairman, Ladies, and Gentlemen, I should hardly have ventured to rise if some remarks which Mr. Boyd was kind enough to make with reference to a body with which I am intimately connected, and whose pride and pleasure I may say are associated not only with the meeting to-day, but with the interest and advancement, intellectual and moral, of the town of Newcastle, had not induced me to do so. We are assembled here to-day to do honour, as Mr. Boyd in his singularly appropriate language has expressed it to you, to the great man whose statue has just been unveiled. Mr. Boyd asked the question, with great propriety, whether great men who have served their country in any branch of action or thought need any monument; and he was disposed, quoting those great words of Milton with reference to Shakspeare, to answer the question in the negative. Undoubtedly, sir, that great man [pointing to the statue] needs no honour from us. Whether we honour him or not, whether we honour the Watts and Stephensons and the great men of our country or not, their fame will force itself upon the knowledge of the whole world. But though he does not need it, we need it. It is we who are honoured in honouring genius and virtue. It is the proudest opportunity which a nation can possibly have; it is the greatest means of encouraging its sons hereafter to like deeds when, on an occasion like this, it meets in such numbers as I am proud to see gathered together to-day to do honour to the memory of a truly great man; and I must say that the man whose statue we contemplate was a truly great man. He was, in the first place, of the practical stamp of the Watts and Stephensons of this country; and although he may not have been endowed with an equal amount of eminence or achieved a similar European reputation, yet he devoted his whole energies—and what can man do better—to objects of great public utility; and not only that, not only was Mr. Wood a man of eminent practical abilities, but (and this is the reason why we who have intellectual and scientific interests especially at heart are proud to honour him) he was a man who, being in a great measure self-raised and self-educated, distinctly saw the enormous advantages of the combination of science with practice. Your President has just read to you a very remarkable quotation, which we were all pleased to hear, from a speech lately delivered by Mr. Gladstone; and he delivered in words complimentary, and at the same time somewhat sarcastic, how you, the miners, by diving into the depths of the earth, perform a more cruel act than even the murder of your parent, by mutilating her while she still lives. Alas, it is too true. We see around us abundant instances of this mutilation; but I may perhaps be allowed to supplement the remark by saying that the same science which tempts some men to mutilate, places in our hands the means of repairing the mutilation. It is—and I wish I could impress it upon practical men as it is impressed upon many of them who are engaged in the work of mining in this beautiful country—it is perfectly within the power of science to preserve the beautiful face of nature even while it draws from her bosom all her rich stores. I am proud to offer the compliment to one, particularly, of my friends whom I see here, in saying, that in the beautiful neighbourhood in which my lot is cast, it is a pleasure to think that we shall not lose the beauty of our woods and of our streams, because he and those who are engaged in the great work of industry, have done the very simple act of forcing their colliers and miners to consume their own smoke. I wish their act was widely imitated by the very large possessors of property, the men of great intelligence and of high position, who, alas! unfortunately, are not so ready to follow the same good example; and I would just make one more remark with reference to what was said by Mr. Gladstone, and it is a remark which has to do with the advantage of combining something like science with practice. He told us that we had already, as it were, soared up into the realms of air; but allow me to tell you that no merely practical man will soar into the realms of air, or that, if he does, he will share the well-known fate of old Icarus. You must have science to teach men how they can soar into the realms of air as well as dive into the depths of the earth; and this recognition of the necessity of combining science with practice is one of the greatest advantages which we derive from the example and teaching of men like Mr. Wood. Well, then, gentlemen, I am loath to detain you at any further length to-day; but it is for these reasons—it is for the pride with which we in Durham have in connection with you in Newcastle—it is from the strong sense that we feel that, having the means of intellectual education in our hands, we wish that we should do a combined work in every respect with the town which of necessity has a much greater practical sphere. It is, in a word, because we rejoice in having been the means of founding here this College of Physical Science that we are so glad to be among you to-day. I would not detract one particle from what Mr. Boyd has said with respect to the immense prospects which this teaching opens out. I would appeal to my friend who sits at my right hand, Sir Wm. Armstrong, whose words I heard with the very utmost pleasure at the banquet with which we inaugurated the opening of this College, when he reminded us that unless we were equalised in science to our eminent neighbours it was impossible that British enterprise should long hold its place in the world. That is one reason, no doubt, why we should found a College like this. But that is not the only, and I do not think it is even the highest, reason. The highest reason is that it will elevate the characters of every class in society. It will elevate the characters of those who are at the head of the mining and engineering interests, because it raises those interests at once into the dignity of a cultivated profession. It will elevate the characters still more of those who may hold the middle and lower positions, because it will place in the hands of every young man of talent, of energy, and of moral good conduct the means of rising as that eminent man did. Well, then, a word more : It is because in the examples of those great men we see such a stimulus to exert ourselves in practice, but still more in that which is the basis of all sound practice, thought; and that which is the highest part of thought, moral and religious feeling, devotion to our neighbours, because we have first a sense of duty to God —it is on all those accounts that we rejoice to be with you to-day, and to do honour to the memory of one of our greatest citizens.

The following gentlemen were then elected—

MEMBERS.

D. H. GODDARD, Branch Bank of England, Newcastle-on-Tyne.
E. GODDARD, Oak Hill, Ipswich.
J. JOHNASSON, 5, Gloucester Square, Hyde Park, London.
G. T. DICKINSON, Wheelbirks, Northumberland.
R. LINSLEY, Seghill Colliery, Northumberland.
G. H. WRIGHT, Heanor Hall, Heanor, near Derby.
R. NICHOLSON, Engineer, Blaydon-on-Tyne.
M. W. PEACE, Wigan, Lancashire.
E. B. MARTEN, Pedmore, near Stourbridge.
P. HILL, Littleburn Colliery, near Durham.
JAMES SPENCE, Printing Court Chambers, Newcastle.
GEORGE DOVE, Portland Square, Carlisle.
J. A. G. ROSS, Elswick Engine Works, Newcastle.
M. W. LAMBERT, 44, Quay, Newcastle-on-Tyne.
RICHARD OWEN, 40, Dean Street, Newcastle-on-Tyne.
C. D. AUSTIN, 40, Mosley Street, Newcastle-on-Tyne.
JOHN LAVERICK, West Rainton, Fence Houses.
J. R. FORSTER, Water Co.'s Office, Newcastle-on-Tyne.
JOHN SNEDDON, 149, West George Street, Glasgow.
JOHN WILSON, 69, Great Clyde Street, Glasgow.
THOS. SLINN, Radcliffe House, Acklington.
W. S. DAGLISH, Solicitor, Newcastle-on-Tyne.
A. S. PALMER, Wardley, County of Durham.
GEO. HUTCHINSON, Howden Colliery, Darlington.

GEO. SCOULAR, Parkside, Frizington, Cumberland.
J. M. REDMAYNE, Chemical Manufacturer, Gateshead.
WM. STOBART, Cocken Hall, Fence Houses.
THOS. TAYLOR, Chipchase Castle, Northumberland.
THOS. ARCHER, Dunston Engine Works, Gateshead.
JOHN YOUNG, 3, St. Paul's Terrace, Newcastle.
R. C. FISHER, Ystalyfern, near Swansea.
JOHN MILLS, Forth Banks Brass Works, Newcastle.
J. F. WEYMOUTH, King's House Engine Works, Sunderland.
C. J. SMITH, Darlington.
J. E. TOLLER, Royal Engineers, Archcliff Fort, Dover.
THOS. FARRAR, Engineer, Barnsley.

STUDENTS.

JAMES LISLE, Washington Colliery, County of Durham,
B. FUGIMATO, 2, Bedford Place, Windmill Hills, Gateshead.
HENRY JEPSON, Durham.
JOHN FLETCHER, Kelton House, Dumfries.
H. N. GROUND, Moor House, near Durham.
W. C. COCKBURN, 8, Summerhill Grove, Newcastle.
J. F. WHITE, Wakefield.
T. Y. GREENER, Peases' West Collieries, Darlington.
HARRY HARGREAVES, Nunnery Colliery Offices, Sheffield.
G. S. BRAGGE, Nunnery Colliery Offices, Sheffield.
WM. MOORE, JUN., Hetton Collieries, Fence Houses.

Dr. PAGE then read the following paper:—

GEOLOGY IN SOME OF ITS PRACTICAL ASPECTS.

BY PROFESSOR DAVID PAGE, LL.D.

It is sometimes asked—though less frequently now than it was a dozen year ago—whether a theoretical knowledge of any science is of essential importance to those who have merely to attend to its practical applications? The sailor, it is said, may navigate his vessel without a scientific acquaintance with mathematics or astronomy; the operative may manufacture chemical products without a knowledge of the laws of chemistry; and the miner may profitably extract from the earth's crust its minerals and metals, and yet be altogether ignorant of the deductions of geology. But while this is true—and it is true only in the sense of making these men the tools of the scientific skill of others—it will surely not be gainsaid that neither the sailor, the operative, nor the miner would discharge his duties less efficiently were he possessed of some knowledge of the principles upon which his own special art is founded. A man may proceed a certain length upon mere empirical skill, but empiricism is always restricted—has no progressive elasticity about it—and is totally helpless when new conditions or unusual phenomena present themselves. It is science alone which can explain such appearances, and suggest the methods by which the new difficulties may be surmounted. Scientific knowledge and the practical applications of that knowledge cannot be dissociated; the more exact and extensive the one, the more certain and successful the other. What is often held up in laudation as "practical skill," is but the result of long observation and deduction, and the wider that observation and more exact that deduction, the sounder and more successful that practical skill. The observation and deduction may not have shaped themselves into any system of science, but they are science nevertheless, and the offspring of much comparing, reasoning, and reflecting; and what is science but the observation of phenomena, the marshalling of facts, and the drawing of legitimate conclusions? A man's practical skill is but the methodical arrangement of his experiences; and such an arrangement is science in the best and truest sense of the term. There can be no antagonism, therefore, between science and art—between theoretical knowledge and its practical applications. This truth is gradually deepening its impression in the public mind, and hence the recent anxiety of civilized nations to disseminate a knowledge of the sciences among their artizans, and to foster their study not only in the higher seats of learning, but in mechanics' institutes and elementary schools. A few, it is true, may still have their sneer at "theory," and their laudation of "practice," but the number of these is rapidly declining, and not many years hence will become altogether extinct and fossil. The practical expression of a truth can never be divorced from its theoretic conception.

These remarks are preliminary to some observations the writer is about to offer on geology; a science which, from its comparative recentness, is still, in a great measure, ignored, and even sometimes made light of, by those "practical men" who would profit most by a knowledge of its deductions. It is true geology has its theories—but what science in its onward progress has not had its fanciful hypotheses and visionary speculations? It is also true that geology has still much to accomplish and a great deal to reject, but it is equally true that the science is pregnant with practical value, especially to the agriculturist, to the land valuator, to the architect, the civil engineer, the mining engineer, and to all, in fine, whose arts and manufactures depend directly or indirectly on the mineral metallic products of the earth. Man cannot make progress in civilization without drawing from the mineral and metallic stores of the earth's crust. He may lead a savage or a nomadic life, and subsist on roots and fruits, by hunting, by fishing, or on the produce of his herds and flocks, but he cannot settle down in civilized communities or combat successfully with the forces of nature till he has learned to arm himself with tools and implements. Personally, he is weak; weaker than many of his fellow-creatures; and it is not till he has furnished himself with implements, and these, the best of them drawn from the earth, that he can till the soil, reap his harvests, hew the wood, fashion the stone, or reduce the ore. And the more numerous his civilised wants become the more he draws from the earth—rearing his cities, decorating his mansions, erecting bridges, piers, and harbours, creating new sources of heat and light, fabricating machinery, laying railways, building steamships, and stretching telegraph cables—the raw materials of which he obtains, and obtains alone, from the earth. In this way a knowledge of the composition and structure of the earth's crust becomes more and more indispensable, and hence an acquaintance with geology if he would learn where this or that mineral is to be found, the abundance in which it occurs, and the facilities with which it can be obtained for his purpose. The minerals and metals are not scattered broadcast through the earth. They have their places and relations, and these places and these relations it is the function of geology to determine. Whoever, therefore, has to deal with the products of the earth in their economic or commercial aspects, cannot fail to be benefited by some scantling of geological knowledge. This may be made clearer by a few illustrative examples.

First, the soils man cultivates depend for their fertility on their composition and texture. This composition and texture may be naturally unfertile, and yet may be capable of improvement by simple admixture of other soils, by drainage, or by mineral manuring. The agriculturist who knows the nature of his soils and subsoils, and of their underlying rocks, is surely, therefore, in a better position to correct their deficiencies by admixture, by draining, and by manuring, than one who cannot discriminate the nature of these soils or detect their deficiencies. The elements of fertile admixture may be within the same farm; the defects in composition may be corrected by the application of appropriate mineral manures; but how can the farmer obtain this needed information, save through a geological acquaintance with the nature of the materials he has to operate upon? "Let him obtain it from the geologist," say some, "and apply it empirically;" so far good, but infinitely better that the agriculturist knew something of the matter himself, and could separate the wheat from the chaff of his scientific advisers.

Secondly, as the worth of an estate depends not only on its agricultural, but also on its mineral value, the land-valuator who is unable to determine the character of its soils and sub-soils, and is ignorant of its mineral structure, can never do justice to his client. A knowledge of the geological structure of an estate is not less necessary to fixing its real value than a knowledge of its various soils and climate, and it is often for want of this knowledge that estates are sold either under their value, or bought at unremunerative prices. At the present day, when farm produce meets so ready a market, and the minerals and metals bring such high prices, no estate should be bought or sold without a thorough survey alike of its surface capabilities and of its mineral stores, and this cannot be done with any degree of satisfaction without appealing to the mineral surveyor as well as to the mere agriculturist. No estate agent is worthy of the name who is incapable of appreciating this twofold aspect of the value of landed property.

Again, take the case of the architect who has to deal with beauty and durability of structure without, and with elegance of decoration within. The beauty and durability of a building stone, and the facility with which it can be obtained dressed, is of prime importance in architecture. The stone which will keep its colours in the open country may not do so in the smoky city; and the rock which will resist the action of the weather in its normal state may waste and crumble under the carbonated atmosphere of the manufacturing town. Nor is it structure and decoration alone that call for the assistance or suggestions of the geologist. The mortars, the cements, and concretes of the builder are yearly assuming a greater importance and receiving a wider application; and as the component materials of these are all drawn directly from the earth, geology comes in with important information to the manufacturer—indicating the nature and abundance of the limestones, sands, and gravels with which he has to operate. It is ignorance on this point which often causes the builder to bring from a distance materials which could be obtained of equal quality and at a cheaper rate in his own immediate locality. It is also a want of knowledge on this head that permits the artificial manufacture of hydraulic cements and concretes, while limestones of natural hydraulic energy lie unknown and neglected.

In the next place, take the case of the civil engineer who has to plan and lay down roads and railways, to execute cuttings and tunnels, to excavate docks and harbours, to erect piers and breakwaters, to deepen and widen tidal rivers, and bring in water supplies to towns. Not a step can he take in any of these important operations without coming in contact with geological phenomena, not a plan can he lay down which does not depend more or less on a knowledge of rocks and rock-formations. It is true, he may obtain information from geological maps and from professional geologists; but, even with this aid, his work will be executed with feebleness and uncertainty compared with that of one who can discriminate the geological structure of a country for himself: and it has simply been, and still is, for want of this geological knowledge that so many of our engineering works have been executed at so much cost and with so little pecuniary satisfaction to their proprietors. The profession of civil engineer is at present a wide and ill-defined one, and greatly needs some qualifying test of admission; but certainly no one should be entitled to add C.E. to his name who cannot show a fair acquaintance with the leading facts of physical geology. Once more, take the mining engineer, whether working among stratified rocks for such products as coal, ironstone, limestone, and fire-clay, or following veins and lodes in search of the metals and metallic ores. In either case some knowledge of geology is indispensable; and though it is true that mining was largely followed ere geology had shaped itself into a science, yet the practical skill of the miner in dealing with successions of beds, with dykes and dislocations, and with kindred phenomena, is geology of a kind requiring the noting of facts and the drawing of generalizations not less real and serviceable than the deductions of the theoretical geologist. The wider, however, the geological knowledge of the mining engineer, the better will he be able to cope with the difficulties that present themselves in his arduous calling. His services may not always be restricted to the same district. His advice may be sought in other districts where there are other rocks, other successions, other dislocations and appearances, and he will be but poorly prepared for these unless he is in some measure acquainted with the general principles of geology. Besides, new substances are yearly being utilised; and it is the duty of the mining engineer to keep pace with this progress, and to see that nothing in his workings be left unnoticed or unused. The writer is old enough to remember when there were only four or five fire-clay works in Britain; now there are scores of them. He has seen back-band ironstone used for a dry-stone wall; now enough of it cannot be obtained for the furnace. Forty years ago the cannel coals of Scotland were seldom brought to bank, and when brought, worth only some four or five shillings a ton; now the same coals are selling at thirty and thirty-five shillings, and the Forbane Hill coal at double that price. Sixteen years ago the bituminous shales of Britain did not bring a sixpence to their owners; now they are bringing hundreds of thousands. Five-and-twenty years ago many may have walked over the Cleveland hills clear in their pastoral purity; now they are beclouded with the smoke of the iron-furnace and resonant with the sounds of a gigantic and varied industry. There is no standing still; not to keep abreast with the progress is to perish. Some of the olden school may affect indifference to science, but the younger members of the profession may lay it to heart that the knowledge which sufficed even twenty years ago will not sustain them in the race of life in these days of gigantic undertakings and more exact calculation. If they will not prepare themselves for the contest, they need not feel surprised at being outstript by those who have had the better sense to seek the necessary scientific training. While every region of the globe is being ransacked to supply the mineral and metallic requirements of Europe and America, the mining engineer may safely calculate upon a wider field for his services; and these services can only be valuable and reliable in proportion to his scientific knowledge of the subjects with which he has to deal. Sinking shafts, driving drifts, pumping, and ventilation are arts of prime importance; but where to sink, the nature of the minerals sought, their mode of occurrence, and the dislocations to which they may have been subjected, are of equal importance, and can only be known through some acquaintance with the science of geology.

It is not alone to the farmer, the land agent, the builder, the civil engineer, or the mining engineer that some acquaintance with geology is of importance. Its applications to the arts and manufactures are numerous and direct; to the fictile arts of the potter and glassmaker, to the manufacturer of mineral pigments and dyes, to the metallurgist and chemist, to the lapidary and jeweller, and even to the mechanical engineer and machinist. The potter and glassmaker derive all their clays and sands from the earth; all mineral pigments are procured, directly or indirectly, from the same source; so likewise are all metals, whether native or as ores; and so also fossil fuels and lights; mill-stones, grindstones, and whetstones; salts and saline earths; gems and precious stones. In fine, there are few of the arts and manufactures which do not, more or less, depend on the mineral and metallic treasures of the earth; and surely some acquaintance with the composition and structure of that earth, so that the place of these minerals and metals may be known, their abundance ascertained, and the facility of obtaining them be determined, cannot fail to be of advantage to those who have to fashion and fabricate them into objects, whether of utility or ornament. It is not required of practical men to go deeply into the theories of geology, for that is impossible, and useless even if it were possible; but surely an intelligent acquaintance with the nature and design of the materials they are daily manipulating cannot be otherwise than a gain, and a source of satisfaction even where the thought of pecuniary gain is altogether out of the question.

Such is a glance, and on a semi-holiday occasion like the present any thing beyond the merest glance would be an intrusion, at a subject of infinite importance to civilized man. Civilization depends in a prime degree upon man's mastery over the opposing forces of nature, and he cannot conquer any force or forces save by the application of a superior one. Physically man is weak and helpless; armed with implements and machinery he becomes a Titan. Without tools and machinery man has to succumb to the forces of nature; equipped with these, they become his willing servants—turning his wheels, raising his weights, wielding his hammers, lessening his labour, and carrying him over land and sea with unparalleled celerity. His main implements and machinery are derived from the mineral world; the heat that sets them in motion is obtained from the same exuberant source. How direct, then, our civilized dependence upon the earth and a knowledge of its mineral and metallic treasures! How important to every art and manufacture to learn something of the nature and character of the source from which they are obtained!

As a geologist perhaps the writer may appear to over-value this knowledge, and may likely be met with the taunt that "there is nothing like leather." He is quite willing to bear it, if only he can succeed in engaging the attention of the younger portion of the practical men now assembled in this Hall. The older section are not likely—unless in rare instances—to be driven from their accustomed routine; in this marvellous age of progress it would be dealing unfairly with the young not to apprise them of the wider range of information they must acquire if they would keep abreast with the demand of the day. The hour is fast passing—if not already passed—when my lord's patronage, my father's name, or my uncle's influence can secure to any young aspirant the place he desires. The ordeal of competitive knowledge is the fashion of the times. Certificates of qualification by authorized boards will shortly be demanded in mining and civil engineering as they are already in other departments. With all this gathering and growing around, it behoves every one, in his own special department of science, to point out its utilities and advantages, and to do what he can for its recognition and dissemination. This, so far as the writer's branch is concerned, he has briefly endeavoured to do, and he trusts the few remarks he has offered will not be altogether unacceptable to this assemblage of shrewd heads and minds, of very practical tendencies.

Mr. Steavenson proposed a vote of thanks to Dr. Page for his very able paper on a very interesting subject.

The Chairman begged himself to second the vote of thanks. He thought the paper very well deserving of it. In common with every one who really understands the nature of scientific education, he concurred most thoroughly with all Dr. Page had said, and in particular, from his own official duties in connection with the scientific education of young engineers, he might state his firm conviction that a knowledge of geology is absolutely essential to the students in this branch. He was sure that anybody connected with the scientific education of professional men of every kind whose professions were connected with the earth's crust and its materials would concur in that opinion; and he had to express now to Dr. Page the thanks which the meeting had just passed.

The meeting was then adjourned until the following morning at half-past ten.

PROCEEDINGS.

JOINT MEETING WITH THE INSTITUTION OF ENGINEERS AND SHIP BUILDERS IN SCOTLAND, AND THE SOUTH LANCASHIRE AND CHESHIRE COAL ASSOCIATION, JULY 3RD, 1872, IN THE WOOD MEMORIAL HALL.

PROFESSOR RANKINE IN THE CHAIR.

Professor RANKINE, in opening the proceedings of the day, said they would observe that it had been announced that the chairman of that day was to have been Mr. Joseph Evans, President of the South Lancashire and Cheshire Coal Association, in order that that distinguished Society might be represented, it being one of those whose members were now enjoying the hospitality of the North of England Institute. But, unfortunately, Mr. Evans was necessarily absent, he being detained in London to attend to the progress of the Mines Regulation Bill. In fact there were a great many gentlemen, Mr. Peace and others, who otherwise would have been present at that meeting, but had been detained in London in order to attend to the progress of that most important bill. In the absence of Mr. Evans, he proposed that, in order that the chairman might still represent the South Lancashire Coal Association, Mr. John Knowles take the chair.

Mr. KNOWLES having taken the chair, thanked the meeting for the honour done through him to the Association of which he was a member. He was sorry that the President had not been able to be present, and, also, that they had lost the presence of many gentlemen who had been detained in London on the important business of the Mines Bill.

Mr. W. COCKBURN then read the following paper "On the Carboniferous Limestone of South Durham and North Yorkshire."

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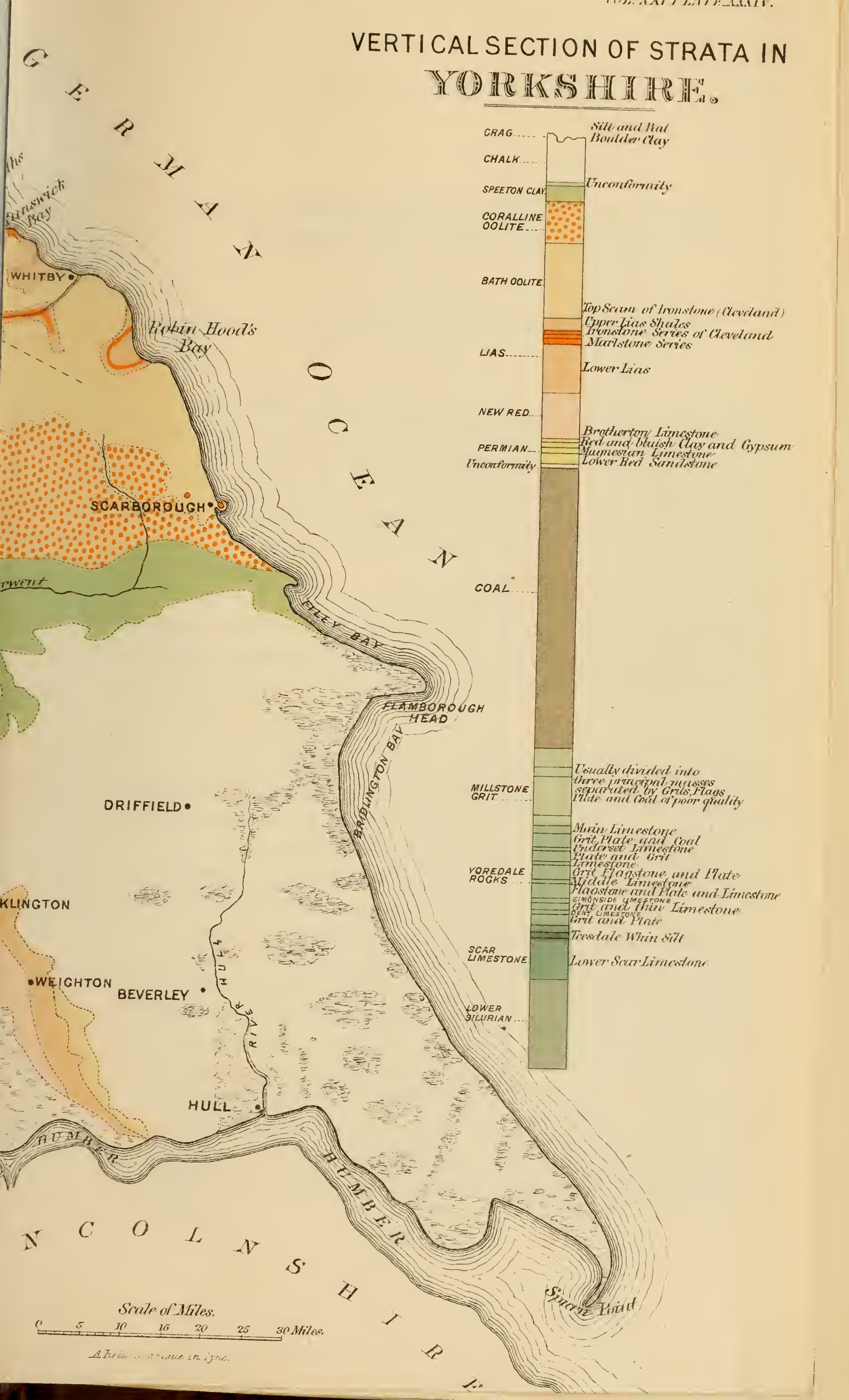
A GEOLOGICAL MAP OF YORKSHIRE.
1872.


VERTICAL SECTION OF STRATA IN
YORKSHIRE.
CRAG
Silt and Bat Boulder Clay
CHALK
SPEETON CLAY
Unconformity
CORALLINE OOLITE
BATH OOLITE
Top Seam of Ironstone (Cleveland)
Upper Lias Shales
Ironstone Series of Cleveland
Marlstone Series
LIAS
Lower Lias
NEW RED
Brotherton Limestone
Red and bluish Clay and Gypsum
PERMIAN
Magnesian Limestone
Unconformity
Lower Red Sandstone
COAL
Usually divided into three principal masses separated by Grits, Flags Plate and Coal of poor quality
MILLSTONE GRIT
Main Limestone
Grit, Plate and Coal
Underset Limestone
Plate and Grit
Limestone
YOREDALE ROCKS
Grit Flagstone and Plate
Middle Limestone
Flagstone and Plate and Limestone
SIMONSIDE LIMESTONE
Grit and thin Limestone
DENT LIMESTONE
Grit and Plate
Teesdale Whin Silt
SCAR LIMESTONE
Lower Scar Limestone
LOWER SILURIAN
GERMAN OCEAN
WHITBY
Robin Hood's Bay
SCARBOROUGH
FILEY BAY
FLAMBOROUGH HEAD
BRIDLINGTON BAY
DRIFFIELD
KLINGTON
WEIGHTON
BEVERLEY
HULL
RIVER HULL
HUMBER
Spurn Point
LINCOLNSHIRE
Scale of Miles.
0 5 10 15 20 25 30 Miles.

ON THE CARBONIFEROUS LIMESTONE OF SOUTH DURHAM AND NORTH YORKSHIRE.

By WILLIAM COCKBURN.

In Volume XVIII. of the Transactions of the Institute a paper on Mining in the Mountain Limestone was read by Mr. T. J. Bewick, C.E., F.G.S., and it occurred to the writer that it might not be out of place to read a paper on the Working of the Mountain or Carboniferous Limestone, especially as that gentleman stated, at the outset, that it had not received so much attention from the members as the coal and iron fields of the east coast.

Within a short time this limestone has given rise to an important industry, it being an essential element in the smelting of iron ore, which has risen into gigantic proportions in this district and is still progressing onwards at a rapid rate, thereby causing demand for limestone to be on the increase.

In the year 1868 the quantity of pig iron made in the North of England district, including Newcastle, Durham, Cleveland, and Whitby, was 1,233,418 tons; and, as the writer is informed by gentlemen immediately connected with that branch of industry, that it requires from 10 to 12 cwts. of limestone to make 1 ton of pig iron, there must have been a consumption of 678,379 tons of limestone. In 1869 the make of pig iron was 1,459,508 tons, and the consumption of limestone 802,729 tons. In 1870 the make of pig iron was 1,695,377 and the limestone required was 932,457 tons; and in the year 1871 the make of pig iron had reached 1,884,239 tons, and the limestone required to smelt it 1,036,331 tons, and this independent of the regular consumption for agricultural purposes and building, so that it will be seen from these figures that its extraction forms no mean part of our industry.

The geographical extent of the mountain limestone, as stated by Mr. Bewick, is 4,000 square miles. It comprises the counties of Northumberland, Durham, Cumberland, Westmorland, Yorkshire, and Lancashire. This paper is confined to the county of Durham and part of Yorkshire.

Taking Stanhope-in-Weardale as a starting point, the mountain limestone is fully shown, and favourably situated for open quarry work, and is extensively worked by Messrs. Ord and Maddison; it is also extensively worked at Newland Side. Messrs. Bell Brothers have recently opened out a quarry at Jack's Craggs, and Messrs. Pease have extensive royalties at Frosterley and Broadwood, while further towards Middleton-in-Teesdale is the Old Bishoply quarry, and another belonging to Ord and Maddison; also one recently opened out at Fine Burn by Mr. Jacob Walton.

Plates Nos. XXXV., XXXVI., and XXXVII. show sections of Stanhope, Frosterley, and Broadwood respectively. Analyses of the stone from these quarries will be given.

Plate XLI. shows a clay dyke running through Broadwood, or rather between that place and Bishopley, which clay dyke completely cuts off all the limestone: how far it goes down the writer has not been able to prove, but an under-level drift many feet below the limestone now being driven may throw some farther light upon it. There are two cross veins shown running through this quarry, crossing the river Wear to a considerable distance up the north bank. These veins of ironstone, as they are called, materially affect the limestone in their passage.

From this point, marked on Plate XLI., the limestone rapidly descends beneath the river Wear, and so continues until it reaches Wolsingham station, where the first patch of limestone is to be seen. A line drawn from this point across Durham and Northumberland to near Radcliffe, shows the first limestone of the carboniferous series.

From Stanhope to Middleton-in-Teesdale, and up to the High Force, no quarries are in operation until reaching Teesdale. The river Tees, as is well known, takes its rise among lofty and lonely mountains on the Penine chain. The main stream comes from Cross Fell, and continues to gather until it falls over Cauldron Snout, and forms the boundary between Yorkshire and Durham. From Maize Beck a very interesting and instructive lesson may be learned by geologists, and the description of it by Professor Philips so exactly coincides with the writer's own experience, that he may be pardoned quoting it. The Professor says:—"For about two miles above Cauldron Snout, Maize Beck runs on the greenstone; then Limestone Rock (called Tyne Bottom Limestone) appears over the greenstone, and continues without interruption to the western front of Dufton Fell, in Westmorland, where the greenstone appears again below this limestone, but reduced in thickness to 24 feet."

It may be added, that for a short distance Maize Beck divides Yorkshire and Westmorland. Proceeding down the Tees from Cauldron Snout, it will be found that greenstone continues in bold cliffs with limestone over it, the limestone being in some places bleached and re-crystallized where it comes in contact with the trap, so as to resemble coarse statuary marble. Examples of this may be seen at Cronkley Scar, Plate XXXIV.

The waterfall called High Force is about 70 feet high and runs over greenstone, which rests on shale and limestone. The shale shows evidences of prisms, from the heat of the trap; the limestone underneath not being bleached like that above. This fall is generally seen rushing over the rock in one grand sheet, but when it descends in two currents, as the writer on one occasion saw it, the effect is extremely fine. Below the High Force high cliffs of greenstone run parallel with the river on the south-west side to Lorton.

At Middleton-in-Teesdale the basalt is extensively quarried near the railway station by Messrs. Ord and Maddison, and sent to several parts of the country for road material. The face of the quarry opened out here is about 80 feet perpendicular. See Plate XXXV.

While on a visit to this district the writer had an opportunity of seeing two of Burleigh's rock drilling machines at work. As it is well known that material such as basalt is very difficult to work by manual labour, it may not be out of place to state here the results obtained from the use of these machines.

The first machine was driven by a perpendicular boiler, of 3-horse power, at a pressure of 60 lbs. per square inch, at the rate of one inch per minute, the drill being $1\frac{1}{4}$ in. diameter. The second machine, drilling a hole 3 in. diameter, was driven a little slower by a boiler of the same description as the above, but considerably larger. These machines are on the percussion principle, and are so placed upon their carriages that they can be applied at any angle that may be required. It cannot be denied that the work done by them is well done, but, in a financial point of view, considering the original cost of a machine (£217 complete for driving a drill of $1\frac{1}{4}$ in. diameter), and the great amount of wear and tear, the writer would hesitate to recommend their adoption in place of hand labour, more especially in working limestone, as the results obtained from working basalt are not so satisfactory as was expected.

The Cockfield Dyke, known also as the Great Whin Dyke, the Willington Dyke, and the Auckland Dyke, will be found shown on Plate XXXIV. as accurately as could be made out from personal observation, from information kindly supplied by various gentlemen, and with the assistance of Professor Philips's map of Yorkshire. The first-named Dyke, commencing at or near Middleton-in-Teesdale, passes in an E.S.E. direction, cuts through the upper part of the mountain limestone and through the coal measures, catches a little of the western crop of the magnesian limestone, and crops out again both at Preston, near Yarm, and near Nunthorp. At Langbray ridge it is extensively quarried for road material, and passes south of Roseberry, through Kildale and Lonsdale, past West House and Castleton, and so on to the Valley of the Esk, where it is lost to view between Slights and Maybecks, having run a course, with very slight divergence, of above 70 miles.

Through the kindness of Mr. T. Allison, of Guisborough, an analysis, made by Mr. W. Crossley, is given of the filling-in of this dyke. The specific gravity of this stone is from 2·5 to 3·0.

ANALYSIS.

Water and carbonic acid	2·30	per cent.
Silica	58·40	„
Alumina	14·70	„
Protoxide of iron	10·27	„
Lime	7·80	„
Magnesia	2·00	„
Potash	4·80	„
	100·27	

It is not the writer's intention to touch upon either the Willington or Auckland Dykes as they do not materially affect the limestone. It was intended to have presented with this paper a horizontal as well as a vertical section from Stanhope to Middleton-in-Teesdale, but at present it has not been possible to accomplish this beyond giving the vertical sections given in Plates XXXV. to XL. In Plate XL., sections of strata at Carr's Cragg, there are 72 divisions of the local names classed under four heads, viz. :—limestone, plate, sandstone, and hazel. There are 306 feet of limestone, 786 feet of plate, 60 feet of sandstone, and 258 feet of hazel. This section was carefully taken by a local gentleman whose remarks thereon are given below, and for the accuracy of which the writer can vouch, from having made a careful personal examination of the strata.

1.—The grindstone sill or millstone grit is most conspicuously seen at Carr's Craggs. Millstones are lying on the place cut by Simpson of

Langdale, of very large size, and there are stones at present which may be cut to any size as far as 13,000 solid feet, or 39 feet in length, according to the information of W. Cameron, Mason, and adapted for any building purposes. This sill is firm and sound.

2.—This large plate bed in different parts contains large quantities of iron ore, but the lower plate beds contain the most.

3.—This hazel sometimes produces fine slates to the thickness of 5 or 6 slates. Thick flags may also be got at the bottom.

4.—Iron is contained in this plate bed.

5.—This limestone, or Fell top lime, when lying bare at the surface, gives a red appearance to the earth, thereby showing the presence of iron.

6.—This hazel contains a great number of cockle-shaped shells as well as those of other descriptions.

7.—This plate bed contains a great quantity of iron ore as is evident by the red water flowing from it.

8.—In some places this hazel contains slate, but generally of too soft a nature for slating purposes.

9.—This plate bed contains small quantities of iron ore.

10.—This hazel is quite brittle and contains very much iron ore.

11.—This plate contains small particles of iron ore.

12.—The upper slate sill is useful for masons as it contains slates, flags, firestones, and wherever it is found it is worked on account of its great utility.

13.—This plate contains iron ore.

14.—This sill is valuable for building purposes. An excellent lead mine is worked here at Wire Gill by the London Lead Company.

15.—Contains iron in abundance.

16.—The hazel or high Pattinson sill contains a great number of shells of a very light nature.

17.—These plate beds contain in abundance large quantities of iron ore.

18.—Freestone is of a very coarse nature but has produced very good lead ore at Cold Berry (the London Lead Company's mine), and is said to produce iron ore likewise.

19.—This large plate bed contains a vast quantity of iron ore, and where a level is driven there issues very thick iron water. It may here be observed of this water that, if properly applied, it is said to be a cure for the itch. There are no doubt a great many iron veins in the

Duke of Cleveland's manor, exclusive of the iron in the beds of plate, which generally lie in flats of 1, 2, 4, 7, 10, and sometimes 12 inches, and are very advantageous in driving levels.

20.—The low Pattinson sills are very productive of lead, especially in weak veins.

21.—This plate is of quite a soft nature.

22.—The little limestones are productive of lead ore, especially in the veins, which also produce blue, grey, green, and white ores in abundance.

23.—This sill seldom fails to produce lead ore.

24.—Plate of a grey beddy nature, where the veins are sparry or riderey they produce ores.

25.—The upper coal sill is productive of lead ore and has a small coal seam upon it commonly called Cran coal.

26.—This plate bed is much the same as the above No. 19 bed, of a grey, beddy nature, producing ores where there is a space ridered.

27.—The lower coal sill is productive of lead ore, especially in the veins. There are also veins producing ores, though of a harder nature.

28.—This plate bed is of quite a soft nature and has a small coal seam at the bottom of it.

29.—This is called the great limestone, and from its value it may not be improper to call it the mother sill of the earth. It produces lead ores, especially in flats where there are a number of veins. The value of the lime produced by burning it is very great; this lime when laid on the coldest and coarsest land gives an immense increase of corn, vegetables, and herbage. The land under which it lies is easy to distinguish from other lands by the nature of its produce. This has been proved by laying it on boggy land without sowing any seeds, and the result has been a production of a great variety of all sorts of useful herbs, good for food, milk, and honey.

30.—This tuft is productive of stone that will resist fire; it is therefore useful in kilns; the purest water also issues from the top of it.

31.—The plate bed produces iron in small quantities.

32.—This limestone is seen at Stoney Gill Head, and is of a hard nature.

33.—This plate contains small particles of iron ore.

34.—Is of a sulphury nature, and produces red or iron water.

35.—This plate contains some iron, but is more of a grey, beddy nature.

36.—This is useful to masons as it produces slates, flags, &c.

37.—This plate is excellent for driving levels in, for draining or letting off the water, and is productive of iron.

38.—This is of a hardish nature, producing bad ore, water springs from it that has the power of marmoration.

39.—This is of a very grey, beddy nature.

40.—Out of this, hazel ore has been dug at Grasshill and other places; it is of a hard nature with strong posts in it.

41.—This plate contains a rather strong grey bed and iron ore.

42.—This is more of a dun, shelly nature than most of the other limestones.

43.—This is soft and contains a strong cran-coal seam, 2 feet thick in places, useful for burning lime; it is used in Harwood for domestic purposes.

44.—Wearhead Bridge stands in this sill. It has produced lead ore at Harwood, Grasshill, Hawkesyke, &c., and is useful for building purposes.

45.—This plate is of a soft nature, and therefore of importance in levels, &c.

46.—The water that proceeds from this sill is of a petrifying nature, and deposits incrustations of marble at its spring.

47.—This is quite hard, grey and beddy.

48.—This has yielded a large quantity of ore at Hawksyke, in Harwood.

49.—This bed is quite shivery and important in driving quick levels.

50.—Has been productive of lead ore at Willey Hole, Troph Head, and Scarhead, in Harwood.

51.—This is of a soft nature.

52.—This is hard and sulphurous.

53.—This is of a soft and murky nature.

54.—This is of a soft nature and suitable for bricks if properly prepared.

55.—This bed is soft and shivery, and contains small particles of iron ore.

56.—This is of a close hard nature and has produced ore at Willey Hole, in Harwood.

57.—This is of a sulphurous and hard nature.

58.—This is grey, beddy and impregnated with iron.

59.—This sill is open and hard, and shells of various descriptions are imbedded in it; hence the purest water springs from its bottom.

60.—This is quite of a soft nature, and in it are embedded screw shells.

61.—This contains a great deal of sulphur and copper, and is of a hard igneous substance.

62.—This is of an adamantine nature, and impregnated with iron.

63.—This bed is of a strong slaty nature, and has sometimes produced lead ore.

64.—This is a close and firm sill, and is productive of lead ore, generally in flats.

65.—The top and bottom of this sill in their natures are very opposite, the top is of a hard sulphurous nature, the bottom the reverse.

66.—This is of quite a soft and lightish nature.

67.—From this sill very fine stones have been dug for sharpening razors, &c.; it is seen at the Wheel and Cauldron Snout.

68.—The great whin sill is of a very hard nature, and is the most valuable sill known for making roads; it is clearly seen at Falken Clint, on the south side of Cauldron Snout, where it shows a face of 20 fathoms perpendicular; it may also be seen at High Force and Holweck Scarrs a great height; every sill in the section, from the bed of the great limestone, has produced ore, notably at Pasture Grove, Weardale (Col. Beaumont's). This is the deepest sill wrought.

69.—This is of a hard and durable nature.

70.—This is at the top and bottom of the whetstone hard, but at the centre fine pencil may be obtained for school use.

71.—Black marble; this is of an extremely hard nature and full of shells. In Westmorland this sill has produced lead ore, but in Teasdale it is as yet unexplored; it is seen at High Force very clearly.

72.—This may be cut into large masses, and would be useful in slating houses, &c.; it is seen at High Force.

Referring back to the greenstone at Lonton, near Middleton, limestone is found cropping out into Lunedale, and prominently shown at Mickelton and various other places. There is not so much prominently developed limestone about Mickelton as the Millstone Grit is overlapping the limestone at Romaldkirk and Cotherstone, extending up Balderdale and Lartington, and so by Startforth and Deepdale. At God's Bridge the Greta enters the limestone, and proceeding on its course passes Rutherford Bridge, Stargill, Brignace, and Greta Bridge, into Rokeby, a little below which it joins the Tees. At Bowes and Boldron the mountain limestone is again fully developed, and crops out to the surface.

Quarries have been opened out by various parties and worked, but only to a limited extent. The section below is taken from a quarry which is being opened out, and only part of it is laid bare.

BOWES' QUARRY.

		Ft	In.
Bed No. 1—Limestone	... ...	10	0
„ „ 2— „	... ...	5	0
„ „ 3— „	... ...	5	0

Remainder not opened.

The writer was informed that this quarry was not what the proprietor expected it to be, which was what might have been anticipated from its position. On the west side of this quarry there are two others, and on the south side of the Bowes' and Greta Bridge road there is a bold cliff of limestone upwards of 70 feet in height.

In reference to this district Professor Philips, after describing various antiquities preserved at Rokeby, says :—" The line of country drained by the Greta deserves the attention of the geologist for another reason; this being the great line of transport of the erratic blocks from the Cumberland Alps towards the eastern parts of the island—thus presenting one of the strangest phenomena of physical geography. Some of these blocks may in fact be traced from their parent mountain at Shap and Cannock, across Edendale to Brough, and up the slope towards the summit of Stairmoor; on the eastern side of the summit they follow radiating lines towards Romaldkirk, Cotherstone, Barnard Castle, Brignall, and are scattered over many parts of the vales of Cleveland and York, the sides of Eskdale, the cliffs of Scarborough, Flamborough, and Holderness.

The outcrop of limestone can be traced from the last-named quarries at Boldron and Rokeby down to Whorlton, Wycliffe, and Forcett, extending inland to Hutton Aalton, Gaylee, and Wharton—the mile-stone just intervening between Forcett, Stanwick, and Aldbrough, down towards Melsonby : or, in other words, from Gatherby Moor down nearly to Moulton.

SECTION OF FORCETT LIMESTONE QUARRY.

The average height may be taken at 40 feet, although at the crown of the hill a little more puts on, which has been proved by boring to have increased its height to 53 feet. The 40 feet worked is divided into 20 beds, as per following section :—

			Thickness. Ft.	In.	Feet.	Inch.
SOIL					8	0
Blue Limestone.	Limestone.	No. 1 Bed.	0	10	39	7
	Do.	„ 2 „	1	10		
	Do.	„ 3 „	1	2		
	Do.	„ 4 „	1	0		
	Do.	„ 5 „	3	5		
	Do.	„ 6 „	3	0		
	Do.	„ 7 „	2	4		
	Do.	„ 8 „	2	0		
	Do.	„ 9 „	3	0		
	Do.	„ 10 „	2	2		
	Do.	„ 11 „	2	6		
	Do.	„ 12 „	3	8		
	Do.	„ 13 „	1	9		
	Do.	„ 14 „	0	11		
	Do.	„ 15 „	1	0		
	Do.	„ 16 „	2	0		
	Do.	„ 17 „	0	9		
	Do.	„ 18 „	3	0		Very inferior in quality.
	Do.	„ 19 „	1	9		
	Do.	„ 20 „	1	6		

Bed No. 17 in the section contains a large quantity of magnesia, and Nos. 18, 19, and 20 being of inferior quality, have been left unworked over most of the quarry. There is a vein running N.W. and S.E., cutting the royalty into two parts. The west side of this quarry is thrown down considerably by this fault; the vein crops out half a mile below the village of East Layton, where it can be seen advantageously. It is worked for copper at Middleton Tyas, near Barton. The extent of Forcett quarry is 120 acres. See analysis, given further on.

At Forcett limestone is now very extensively worked for blast furnace purposes. This limestone was used originally for agriculture and building only, but the increased demand for it has caused new fields to be opened out, of which that at Forcett is one.

A new railway has lately been constructed (the Merrybent and Darlington), which leaves the Darlington and Barnard Castle branch of the North-Eastern at or near the township boundary line of Cockerton, and proceeds to its terminus at or near the High Street, with a branch running from it. Particular reference is made to this line of railway, as it goes into a limestone district (of which a fuller description will be given) that has for many years formed the source from which agricultural and building lime have been derived.

Following up the remarks upon Forcett, and allowing for a small patch of millstone grit between Forcett and Melsonby, in the neighbourhood of Stanwick and Aldbrough, it will be necessary to define more particularly the district opened out by the line of railway just spoken of, as far as Leybourne, beyond which it is not intended to proceed in the present paper, although the writer hopes to be able to do so on a future occasion.

From Moulton, in addition to the trias or new red-sandstone, a large portion of millstone grit covers the country down to Holtby, which is nearly in a line with Leybourne. Between the two last-named points, Gilling, Aske, Uckerby, Hipsuell, Hawkswell, and Bellerby, are situated on the millstone grit, and patches of the limestone occur at Marske, Stainton, and Downholme, while close on the outcrop edge, but not yet developed, there is a patch of magnesian limestone at Brough and Catterick.

The writer is able to define the above-named field, from having recently visited the district. The old Barton quarry is situated about 3 furlongs 143 yards, or nearly so, from the town. The limestone in this quarry has in former times been worked to the depth of about 30 feet. And it is reported that a well was sunk in it 24 feet deep, and the bottom of the limestone was not even then reached. In a field adjoining the High Street, a limestone quarry has originally been worked to the depth of about 25 feet, the limestone continuing still deeper. At Ducket Hill a quarry is partially opened immediately adjoining the High Street, the section of which is as follows:—

		Ft.	In.
Baring soil ...	... ...	4	0
Limestone, 1st Bed	... ...	4	0
Do.	2nd „	2	6
Do.	3rd „	2	0
Do.	4th „	1	0
Do.	5th „	2	6
Do.	6th „	4	0
Do.	7th „	12	0
Do.	8th „	3	0
		31	0

The remainder of the quarry had not been opened, but the writer was informed that it was about 30 feet thick; see Plate XXXVIII. A bore hole was put down immediately adjoining the High Street, and only 100 yards from the aforesaid quarry, but no limestone was found. The dip is here N.E., and the termination of the railway is about 40 or 50 yards across the street. A little beyond this point an under level drift is being driven, and at 60 yards from the mouth is completely underneath the limestone, which proves the dip to be N.E. There are two pits sunk immediately on the line of this drift, through the limestone, which looks shaley and much broken up.

A very considerable quantity of copper was found here by the Company, close to the surface, and a pit having been sunk 50 fathoms, further search for copper was being made.

In an examination of this district, it is found that the millstone grit and the top of the limestone are very difficult to identify, especially between Forcett, Aldbrough, Stanwick, and crossing Gatherly Moor, where the millstone grit has been quarried to a considerable depth. The piece of limestone lying between Barton and Low Hang Bank, and the road from Barton to Middleton, including Merrybent, Melsonby limestone kilns, a portion of Middleton Caves and the quarry at Barton, shows a very good face; thence, continuing this line on to Little Hang Bank Bridge (where a face of quarry is standing), and on to Melsonby kilns, it still shows a good face. A vein, of what dimensions could not be ascertained, after running nearly parallel with the Melsonby and Barton road, throws it down almost immediately opposite the Melsonby lime kilns, and cuts it off from view on the opposite side of the beck in West Pasture, where the hole previously mentioned never found it. A little further E. a sandstone quarry is standing open at Mickelhow Hill, which, in fact, is a part of the millstone grit.

In Bussey's Quarry the height of the limestone is at least 23 feet, and probably 15 or 16 feet more. The dip is nearly N.E., and about 10 inches to the yard, being very much affected by a vein at about 150 yards S. There is also another vein running nearly E. and W., and a pit put down immediately east of it proved the limestone to be only 9 feet thick.

At Hartforth Lane End all trace of the limestone disappears. This lane runs in a westerly direction, and about 400 yards S. and E. a cross vein cuts the limestone, and it must be thrown down a great depth as the millstone grit is quarried to the depth of 25 feet about half a mile south of it. Mr. Wallace, in his "Mineral Deposits," says, "The total thickness of this limestone is about 2,800 feet, and consists of a series of alternating strata of limestone, sandstone, and shale, and one layer of trap." The number of feet is given on the section as 1,410; but Mr. Wallace gives the aggregate on Alston Moor to be 1,037 feet, and compared as follows: limestone, 183 feet; sandstone, 349 feet; and shale, 505 feet.

As stated at the commencement of this paper the consumption of limestone in this district, for smelting purposes alone, is the enormous quantity of more than a million tons, and the three great sources from which that supply is obtained are Weardale, Forcett, and Merrybent, although there are other places from which limestone is obtained. The following table shows the quantity sent from Weardale for the three weeks ending 22nd June, 1872:—

	Tons.	Cwts.
Newlandside	7,964	17
Bell Brothers	1,093	8
Frosterley	4,158	3
Broadwood	17,901	11
Bishopley	1,172	7
Fine Burn	3,748	14
Forcett	3,600	0
	39,639	0

This shows an average of more than 13,000 tons per week, equal to about 700,000 tons per annum. The remainder is made up from Merrybent, Raisby Hill, Pickering, and also a little from the district of Bowes and Boldron, but from the figures it will be seen that the Valley of the Wear sends the largest quantity. The reason of this will be apparent from a reference to the following correspondence and analyses supplied by various managers in the Cleveland district. It is worthy of remark that the appearance of the various limestones is widely different, the Weardale being a clear deep blue, the colour changing at Bowes and Forcett to a considerably lighter shade, and at Merybent it gets nearly white. In the districts described a few fossils are found, and the writer has in his possession one or two good specimens, said by competent persons to be of the *orthocedea*.

It will no doubt have been noticed that in the previous remarks no mention has been made of the magnesian limestone, or the oolitic limestone, as any observations thereon could not be sufficiently condensed within the limits of this paper. A seam of the oolitic is passed through in the neighbourhood of Stanghow, in Cleveland, with a bore-hole made by Captain Beaumont's diamond rock-borer. A representation of the outcrop of the limestone, as well as the magnesian (except the magnesian which has not been completed) is shown on Plate XXXIV.

In concluding this paper the writer may be excused quoting the remarks of Professor Page, who, in reference to the mountain or carboniferous limestone, says that it is one of the most distinct and unmistakeable in the whole crust of the earth. Whether consisting of one thick reef-like bed of limestone or of many beds with alternating shales and sandstones, its peculiar corals, encrinites, and shells distinguish it at once from all other strata.

In fact it forms in the rocky crust a zone so marked and peculiar that it becomes a guiding post not only to the miner in the carboniferous system but to the geologist in his researches among other strata.

In the district, which the writer has attempted to describe in the present paper, the mountain limestone is true and fully developed, and certainly forms a very important portion of that system.

In Scotland the limestones of the lower part of the carboniferous system are very thin, as will appear from the following section of the rocks in the country between Edinburgh and Glasgow.

	Feet.
Red sandstone (carboniferous)...	
Alternations of sandstone and shales with coal and ironstone	130·0
Limestone	1·0
Alternations, &c., five beds of coal four feet thick and many others less	1635·0
"Gare" limestone	4·9
Intermediate strata	150·0
Ochrey limestone	3·0
Sandstone with shale, &c., one coal	51·0
Limestone	4·0
Alternations, &c., four beds of coal, two or three feet thick, and many ironstones	405·0
1st Cawmey limestone	1·6
Shale	8·6
1st Kinshaw limestone	2·0
Alternations and one little coal bed	16·4
2nd Kinshaw limestone...	2·1
Shale with ironstone bulls	29·5
2nd Cawmey limestone	4·6
Shale with ironstone band	42·0
Foulband limestone	3·6
Alternations, &c., one coal bed, 1 foot 8 inches thick ...	86·0
3rd Cawmey limestone	2·6
Shale with ironstone band	20·0
Main limestone	4·6
Shale and fire-clay with one coal	29·0
Coarse limestone with intermediate band of fire-clay ...	5·6
Sandstone with shale and a little coal	54·0
Limestone...	2·0
Fire-clay, sandstone, and shale, with one small coal ...	34·0
Oystershell limestone (producta, &c.)	4·0
Alternations of shale, whitish sandstone, and fire-clay ... (Old red sandstone to an unknown depth.)	104·0
Total	2840·1

LETTER No. 1.

In reference to yours of the 14th, on limestones of the district, I think those that suit us best are the purest carbonates of lime. Lime is what we require for fluxing our ironstone, it suits us better than magnesian, and therefore the pure limestones are better for our purpose than magnesian limestones. Any silica or alumina in the stone or attached to it in the shape of dirt is objectionable, inasmuch as it in itself requires a portion of the lime to flux it, and thus the slag becomes short of lime although the proper weight of stone has been put in. My opinion is that the mountain limestone from Weardale is the most suitable we get, as when clean it is very pure. There are several places in what is considered the magnesian limestone country, where a very pure carbonate of lime is worked, such as in Mr. Morrison's workings at Ferryhill, and also at the Raisby Hill quarries. I do not know how it lies with the magnesian limestone bed, but it certainly does not contain more magnesia than the mountain limestone. In appearance it is scarcely to be detected from magnesian limestone. The Raisby Hill is used in the district. The Forcett and Merrybent you will know, but never having worked them I have no trustworthy analysis, but they may both be considered inferior to the Stanhope stone. The Harmley stone has been used more or less in the district, portions of the bed are very good, but in the bulk it is not so good as the Weardale. The Pickering oolitic limestone is used at Grosmont for smelting. It is pretty fair, a portion of it good, but in the bulk inferior to the Weardale.

I do not know I can do any better than subjoin you analyses of the various sorts in use, and I believe they may be considered as fair samples.

ANALYSES.

WEARDALE LIMESTONE.

Carbonate of lime	94·50
Carbonate of magnesia	2·71
Peroxide of iron	0·17
Alumina	0·75
Siliceous matter	1·54
Moisture	0·34
	100·01

FERRYHILL LIMESTONE.

Carbonate of lime	95·74
Carbonate of magnesia	2·12
Peroxide of iron	0·30
Alumina	0·74
Siliceous matter	1·00
Moisture	0·24
	100·14

RAISBY HILL LIMESTONE.

Carbonate of lime...	96·20
Carbonate of magnesia	1·80
Peroxide of iron	0·37
Alumina	0·67
Siliceous matter	1·04
Moisture	0·10
	100·18

MAGNESIAN LIMESTONE.

Carbonate of lime...	57·68
Carbonate of magnesia	39·12
Peroxide of iron	1·48
Alumina	0·60
Siliceous matter	1·20
Moisture	0·13
	100·21

HARMBY LIMESTONE.

Carbonate of lime...	91·52
Carbonate of magnesia	2·77
Peroxide of iron	0·28
Alumina	1·00
Siliceous matter	4·72
Moisture	0·14
	100·43

PICKERING OOLITIC LIMESTONE.

Carbonate of lime...	90·76
Carbonate of magnesia	1·48
Alumina	0·76
Peroxide of iron	0·36
Siliceous matter	6·60
Moisture	0·36
	100·32

LETTER No. 2.

The following are analyses of limestone that we have worked here:—

WEARDALE LIMESTONE.

Silica	0·41
Alumina	0·50
Carbonate of lime	96·70
Carbonate of Magnesia	2·30
	99·91

BOLDRON LIMESTONE.

	Sample 1.	Sample 2.	Sample 3.
Silica	5·68	5·76	2·40
Alumina	0·77	0·55	0·36
Carbonate of lime	91·44	91·38	95·28
Magnesia	1·86	2·40	1·98
Peroxide of iron	0·15	0·08	0·03
Moisture	0·23	0·20	0·17
	100·13	100·37	100·22

RAISBY HILL LIMESTONE.

Silica	1·42
Alumina	0·11
Carbonate of lime	96·23
Do. magnesia	1·75
Peroxide of iron	0·37
Sulphur	0·08
Water	0·15
	100·11

MERRYBENT LIMESTONE.

	3 ft. deep.	4½ ft.	6 ft.	12 ft. deep.
Silica	2·65	2·18	2·00	1·28
Alumina	0·48	0·53	0·38	0·28
Carbonate of lime	95·28	96·53	97·17	97·78
Magnesia	1·75	1·57	1·72	1·72
	100·16	100·81	101·27	101·06

The Forcett limestone is very much like the Boldron limestone, containing from 4 to 7 per cent. of silica. The Weardale, of course, works well upon the furnaces. The Raisby Hill that we got turned out also very good when clean and free from clay and dirt—the latter was against it. The Boldron and Forcett limestones are poor in carbonate of lime, and contain too much silica. The bottom Merrybent is a clean, good stone and calcines very much easier than Weardale; the top Merrybent is rather too soft and friable and falls to dust in the kilns, but it works very well when used as it comes from the quarry; it is difficult to break into small pieces, and does not cleave like the blue limestone. The top Merrybent runs as low as 93 per cent of carbonate of lime.

LETTER No. 3.

I have only used Weardale and Forcett since I have been in the North, of course you will know their per centages as well or better than I do. For furnace purposes I consider Weardale limestone equal to the best in the kingdom.

LETTER No. 4.

Weardale Limestone.—This blue mountain limestone is no doubt the most uniform in quality of any we have ever had and works best in the furnace. The distance, and therefore the price, is against it.

Forcett Limestone.—Except in a bed of about 2 or 3 feet in thickness occurring at the last "lift" but one in the quarry, this stone is very good, and we find it to work satisfactorily in the furnace. Enclosed analysis is a fair average sample of what they are now sending out. They exclude the brown bed above mentioned, and you will see by the enclosed analysis it is necessary to do so.

Merrybent.—The stone they have sent out up to now is not good, and it contains too much silica, which has a tendency to work cold in the furnace and fill up the hearth. They are pushing the workings forward towards the Duchess of Northumberland's Royalty, and the samples we have received from the full face of the seam there are much better, and this stone would without doubt answer our purpose well. It is a clean looking stone of a bluish brown colour, and appears free from fossil remains.

Boldron.—We have never used any quantity of this, but from what I have heard and from analysis we have taken of samples, it works irregularly and contains too much silica (see analysis). The silica varies very much in different parts of the seam, but I never examined the quarry, and cannot say where the good and bad stones occur.

Raisby Hill.—A peculiar deposit of stone of a mountain limestone character in a magnesian district. The bulk of the stone is very pure and good, and with care in working it can be said to answer our purpose well. The seam is much broken up with partings, and the stone is smaller in size and more easily broken than the Weardale. It also calcines more easily. Some portions of the quarry are a browner stone, which must be kept out. Enclosed analyses are of a fair average sample, collected from 200 trucks, and of a sample of the brown stone.

Harmby, near Bedale.—We have sometimes had occasion to resort to this stone in winter. It is rather magnesian in character, and does not act particularly well as a flux, but still I think it might come into the market if carefully and energetically worked.

Aycliffe, Eldon, Ferryhill, and Carlbury are magnesian limestones, containing about 50 per cent. of carbonate of lime, and 40 per cent. of carbonate of magnesia. They do not answer our purpose.

ANALYSES.

Boldron.—Silica, in various samples, from the quarry.

No. 1 =	5·40	(Samples.)
„ 2 =	8·15	„
„ 3 =	13·83	„
„ 4 =	5·32	„
„ 5 =	1·25	„

Raisby Hill.—Dark brown sample.

Carbonate of lime	88·52
Do. magnesia	7·31
Peroxide of iron and alumina	3·20
Silica	0·20
	99·23

Merrybent.—Samples received from the new workings on the Duchess of Northumberland's royalty.

	Top of Seam.	Bottom of Seam
Carbonate of lime	94·67 ...	95·44
Do. magnesia	2·75 ...	2·12
Oxide of iron and alumina	0·40 ...	0·35
Silica	1·70 ...	1·85
	99·52	99·76

Merrybent.—As at first received.

Carbonate of lime	89·61
Do. magnesia	0·69
Peroxide of iron and alumina	1·40
Silica	7·50
	99·20

Forcett.—A fair sample of what they are now sending.

Carbonate of lime	91·430
Do. magnesia	3·268
Peroxide of iron and alumina	1·300
Silica	3·050
Organic matter	0·450
	99·198

Forcett.—From the Brown Bed.

Carbonate of lime	85·37
Do. magnesia	8·42
Peroxide of iron and alumina	4·45
Silica	1·23
Organic matter (water and loss)	0·53
	100·00

Boldron.—Average of one train load.

Silica	5·8655
Oxide of iron and alumina	2·8460
Carbonate of lime	90·8060
Do. magnesia ... ... } Organic matter (water and loss) ... ... }	0·4825
	100·0000

Raisby Hill.—Average sample.

Carbonate of lime	95·14
Silica	1·20
Peroxide of iron and alumina	1·00
Carbonate of magnesia	1·88
	99·22

The fauna of the magnesian limestone in England has been fully treated by King, who presents, in a synoptic table, the following summary of British and Foreign species :—

FAUNA OF THE MAGNESIAN LIMESTONE.

	Totality of Genera.	Totality of Species.	Species occurring in England and Ireland.	Species peculiar to England or Ireland.	Species peculiar to Russia.	Species peculiar to Germany
Plants	17	60	7	? 6	27	26
Spongiæ	4	5	5	5	0	0
Foraminifera	3	6	6	6	0	0
Polyparia	14	18	11	4	5	2
Echinodermata	2	2	2	0	0	0
Annelida	4	5	5	4	0	0
Crustacea................	3	13	12	12	1	0
Palliobromchiate	14	37	23	9	14	0
Lonnellibronchiata ...	19	47	30	16	16	? 1
Gasteropoda	? 10	26	21	? 18	3	2
Cephalopoda	3	4	2	1	1	1
Pisces	? 14	? 45	16	? 16	2 (?) more	27
Reptilla	7	9	3	3	4	2
	114	277	143	100	73	61

Mr. T. E. Scott, of Greenwich, then read some remarks "On Longitudinal Iron Shipbuilding," which, as they have been printed before, have not been reproduced here.

Mr. Thos. Roberts then read the following paper "On the Teeth of Wheels."

Section of Limestone
STANHOPE QUARRY
1872.

Nº	NAMES	STRATA	THICKNESS: BARING Ft.	THICKNESS: BARING In.	THICKNESS: LIMESTONE Ft.	THICKNESS: LIMESTONE In.			
	Soil		10	0					
	Limestone				75	0			

Section of Bysalt belonging to
ORD AND MADDISON.

Nº	NAMES	STRATA	THICKNESS: BARING Ft.	THICKNESS: BARING In.	THICKNESS: BASALT Ft.	THICKNESS: BASALT In.			
	Basalt				80	0			

Scale of Feet
10 0 10 20 30

Andʷ Reid, Newcastle

Section of Great Limestone at FROSTERLY QUARRIES, In the County of DURHAM. 1870.

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.	Shale Ft.	Shale In.	
	Baring		31	0					
1	Limestone				2	8			
	Shale						0	6	
2	Limestone				3	4			
	Shale						1	6	
3	Limestone				5	3			
	Shale						2	8	
4	Limestone				4	11			
	Shale						0	6	
5					2	8			
6					5	3			
7					8	0			
8					5	8			
9	Limestone				6	0			
10					4	0			
11					4	0			
12					8	8			
13					3	8			
14						11			
15					2	6			
			31	0	67	6	5	2	

Great Limestone (Nos. 1–15)

Scale of Feet.

10 0 10 20 30 Feet

Andw Reid, Newcastle

Section of Limestone.

RAISBY HILL, LOW QUARRY.

1872.

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.	Vamp Ft.	Vamp In.	Analysis
1	Soil		5	0					
2	Brown St.		3	0					
3	Magnesian Limestone				62	0			

Section of Great Limestone

AT BROADWOOD QUARRIES,

In the County of

DURHAM.

1870.

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.	Shale Ft.	Shale In.	
	Baring		6	0					
					4	0			
					9	0			
					1	10			
					3	2			
					1	3			
					1	10			
					4	9			
	Great Limestone				2	3			
					4	2			
					2	8			
					2	8			
					1	6			
					3	9			
						6			
					2	9			
					1	2			
					2	2			
	Totals		6	0	49	5			

Scale of Feet

10 0 10 20 30

Andʷ Reid, Newcastle

Average Section of FORCETT LIMESTONE QUARRY, *July, 1872.*

Nº	Name	Strata	Thickness: Baring Ft.	Baring In.	Vamp Ft.	Vamp In.	Limestone Ft.	Limestone In.	Analysis
	Soil		8	0					
1								10	
2							1	10	
3							1	2	
4							1	0	
5							3	5	
6	*Limestone*						3	0	
7							2	4	
8							2	0	
9							3	0	
10							2	2	
11							2	6	
12							3	8	
13							1	9	
14								11	
15	*Black Jack*						1	0	
16	*Magnesian*						2	0	
17	*Yard Post*							9	
18	*Silica*						3	0	
19	*Newcastle*						1	9	
20	*Bottom Bed*						1	6	
		Totals	8	0			39	7	

Section of Great Limestone AT DUCKETT HILL QUARRIES, YORKSHIRE. 1872.

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.
	Baring		4	6		
1	*Great Limestone*				4	0
2					2	6
3					2	0
4					1	0
5					2	6
6					4	0
7					12	0
8					3	0
9					12	6
10					12	0
11					10	6
	Totals		4	6	66	0

10 0 10 20 30 Feet

Andw Reid Newcastle

Section of Limestone
RAISBY HILL, HIGH QUARRY,
1872.

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.	Vamp Ft.	Vamp In.	Analysis
1	Soil		10	0					
2	Magnesian Limestone				74	0			

Section of Great Limestone at
DUCHESS QUARRIES, MERRYBENT
YORKSHIRE.
1870

Nº	Names	Strata	Thickness: Baring Ft.	Baring In.	Limestone Ft.	Limestone In.	
	Baring		2	0			
1					1	6	
2					4	0	
3					3	6	
4					4	0	
5					5	0	
6					3	0	
7	Great Limestone				12	0	
8					12	6	
9					15	6	
	Totals		2	0	61	0	

Scale of Feet.
10 0 10 20 30 Feet

And.w Reid, Newcastle

GENERAL SECTION OF STRATA

As developed in the District between

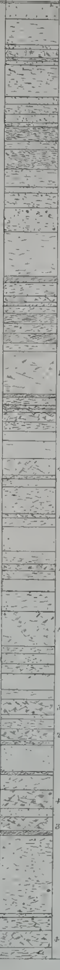
CARRS CRAGG AND HIGH FORCE.

No.	Local Names	Strata	Limestone				Plate				Sandstone				Hazel			
			Fa.	Yd.	Ft.	In.	Fa.	Yd.	Ft.	In.	Fa.	Yd.	Ft.	In.	Fa.	Yd.	Ft.	In.

GENERAL SECTION OF STRATA

As developed in the District between

CARRS CRAGG AND HIGH FORCE.

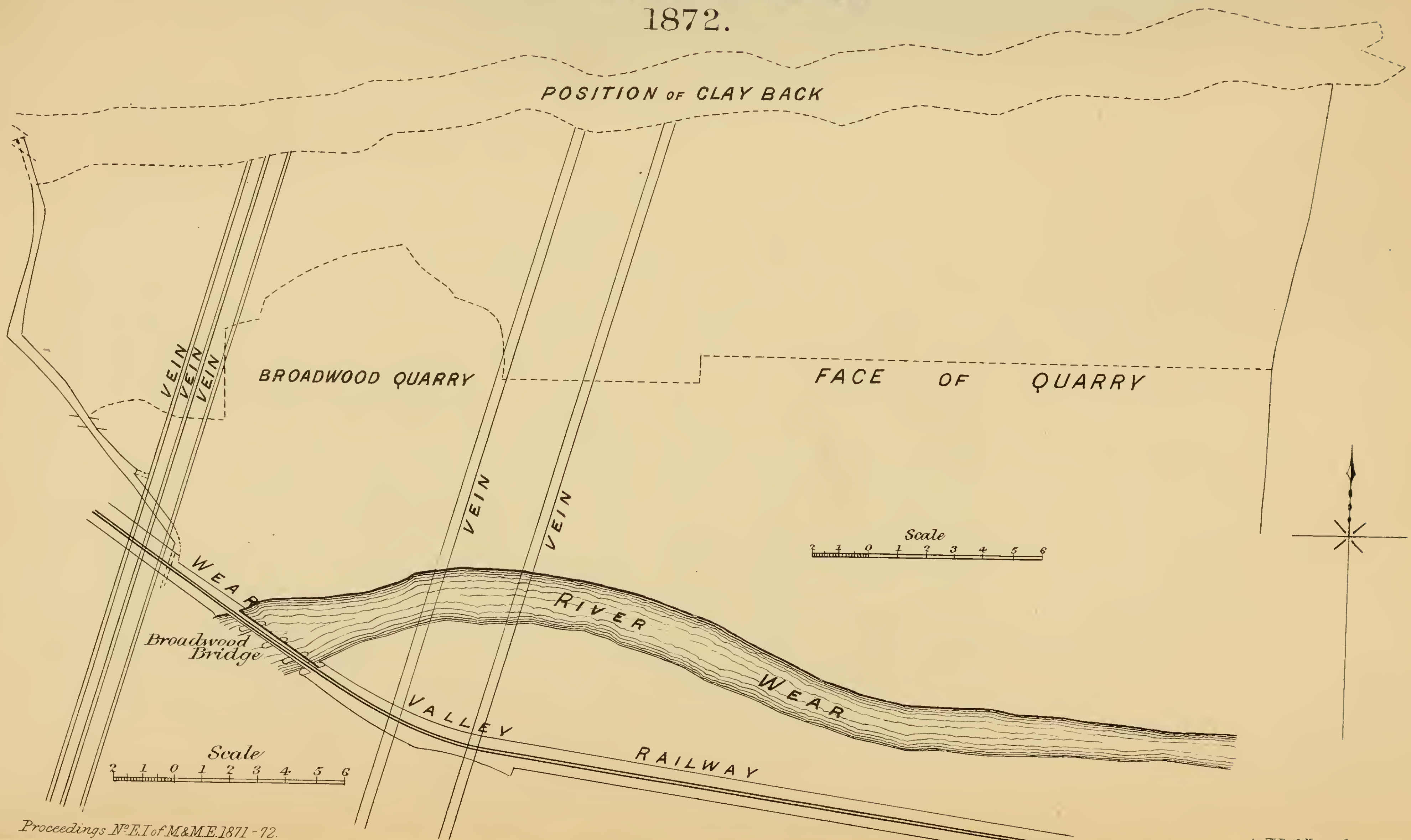


Nº	Local Names	Strata	Limestone Fa	Limestone Yd	Limestone Ft	Limestone In	Plate Fa	Plate Yd	Plate Ft	Plate In	Sandstone Fa	Sandstone Yd	Sandstone Ft	Sandstone In	Hazel Fa	Hazel Yd	Hazel Ft	Hazel In
1	Sandstone										4							
2	Plate						6											
3	Hazel														1		2	
4	Plate						2											
5	Limestone			1	1													
6	Hazel														1		2	
7	Plate						1	1	2									
8	Hazel														2			
9	Plate						2		1									
10	Hazel														2			
11	Plate						1											
12	Upper Slate Sill						3		2									
13	Plate						2											
14	Lower Slate Sill						4	1	2									
15	Plate						4	1										
16	Hazel														1	1	1	
17	Plate						3	1	1									
18	Freestone										5	2						
19	Fatham Plate Bed						11											
20	Pattinson Sill						1	1	1									
21	Plate						3		1									
22	Little Limestone		1	1	2													
23	White Hazel															1	2	
24	Plate						1	1	2									
25	Upper Coal Sill						2	1										
26	Plate						2	1										
27	Lower Coal Sill						2		1									
28	Plate						2		1									
29	Great Limestone		10	1														
30	Water Sill							1	2									
31	Plate						2											
32	Limestone			1	2													
33	Plate						1											
34	Upper Quarry Limestone		2		1													
35	Plate						2		1									
36	Lower Quarry Hazel														2	1		
37	Plate						4		1									
38	Fatham Limestone		4															
39	Plate						1											
40	Hazel														2		1	
41	Plate						5	1	2									
42	3 Post Limestone		1															
43	Plate						2		2									
44	Bridge Hazel														6			
45	Plate						3	1										
46	Limestone 5 Yards		1	1	2													
47	Plate						2											
48	Low Bridge Hazel														3			
49	Plate						4	1	2									
50	Low Great Limestone		8		2													
51	Plate						1	1	2									
52	Hazel under Gt. Limestone														2	1	2	
53	Plate						2	1										
54	Low White Hazel														4			
55	Plate						2											
56	Scarr Limestone		3	1	2													
57	Hazel														1			
58	Plate						2	1										
59	Cockleshell Limestone		2	1	2													
60	Plate							1	2									
61	Hazel														6	1	1	
62	4 Ft Post Limestone			1	1													
63	Tyne Bottom Plate						4											
64	Tyne Bottom Limestone		4	1	1													
65	Hazel														2			
66	Sandy Limestone		3	1														
67	Whetstone Bed						1											
68	Great Whin Sill						10	1										
69	Hazel															1	2	
70	Pencil Sill														3			
71	Jew Limestone		4		2													
72	Grey Slate						3											

Scale of Fathoms

0 10 20 30 40 50

PLAN OF BROADWOOD LIMESTONE QUARRY, COUNTY OF DURHAM. 1872.



Andw Reid, Newcastle

ON THE TEETH OF WHEELS:

An Improved Method of approximating to the True Epicycloidal Forms by Circular Arcs.

By THOMAS ROBERTS.

It is well known how to find forms for the teeth of wheels to work with mathematical accuracy by means of epicycloidal curves, obtained by rolling a suitable "rolling circle" templet on templets of the pitch circles of the wheels; and several methods of approximating to these curves by circular arcs have been published. Some account of these is needful to show the advantages of the new method.

1. Willis's.—What Professor Willis has aimed at, and has actually done with mathematical exactness, is to give the normal or radius of curvature to the epicycloid arc at its middle part.

Plates XLII. and XLIII. show the epicycloid arcs drawn for two cases, viz., straight rack and pinion of 12 teeth, marked O E. Willis's arcs are drawn alongside, marked O W.

In Plate XLIII. his theoretical approximate arc, drawn by the *normal* or radius above mentioned, is also shown, marked *v w*. It coincides very well with the epicycloid arc for about the middle third of its length, but diverges considerably at the ends. But in practice the arc must start from the pitch point O, and then it diverges immediately from the epicycloid arc, is nearly parallel to it at the middle part, and at the outer end attains a double divergence E W, which, in the case shown in Plate XLIII., lessens the thickness of the tooth at the point by about 1-5th. It also starts from the pitch line at a considerable angle with the radius, whereas the epicycloid curve is tangent to the radius at O; the angle, in the case shown in Plates XLIII. and XLV., amounts to 15°.

This is not merely an objection of theory or an objection of the eye, for it introduces a constant pressure, tending to push the wheels apart from each other, and so producing additional wear and loss of work by friction, nearly in proportion to the angle in question.

2. Adcock's.—This method was given as a "Supplement to the Engineer" in 1869. It is the same in principle as Willis's; but Willis gave

the position of his centres by a construction (shown in Plates XLII. and XLIII.) in which a line at 15° to pitch line is drawn at a point half the pitch distance from O, and the distance along the 15° line to the centre is given either by a small table or by the formula,

$$\text{Distance} = \frac{\text{No. of teeth}}{\text{No. of teeth} \pm 12} \times \tfrac{1}{2}\ \text{pitch.} \qquad (1)$$

While Adcock gives at once, by tables, both the radius, and the distance of the centre within or without the pitch line. His radius agrees with the formula:—

$$\text{Rad.} = \frac{\text{No. of teeth} \pm 6}{\text{No. of teeth} \pm 12} \times \text{pitch.} \qquad (2)$$

This being obtained from the former by adding $\frac{\text{pitch}}{2}$ to it. In both cases the + sign is for the face of the tooth or part above the pitch line, and the — for the flank or part beneath the pitch line.

This was for a rolling circle = 6 teeth, or, as it is usually expressed, for smallest pinion = 12 teeth, which is also Willis's assumption. But Adcock also gives tables for rolling circles of 4 and of 5 teeth (or smallest pinion 8 and 10 teeth); and (n being No. of teeth in rolling circle) these agree with the formula,

$$\text{Rad.} = \frac{\text{No. of teeth} \pm n}{\text{No. of teeth} \pm 2n} \times \text{pitch.} \qquad (3)$$

And as these radii, &c., are given for every tooth, from 8 to 300 teeth, the tables appear very elaborate and promise great utility.

But they have the same faults as Willis's method, aggravated by the circumstance, that while the latter is adapted to a height of tooth of about ·35 of pitch, Adcock directs a height of only ·2 of pitch (above pitch line) to be used. The consequence is that the tabular radius is really the radius that is normal to the epicycloid arc almost at the top of his tooth; while a radius normal, at the middle of it, on Willis's principle, would have been a better approximation.

The diameters of the wheels are given in these tables on the supposition that the pitch is the straight line distance between pitch points, making the diameter of a 10-tooth pinion 3·236 times pitch, instead of 3·183 times, as it ought to be; while for the higher numbers of teeth such a loose value of π seems to have been taken as to make the diameter for 300 teeth 95·474, instead of 95·493 times pitch, while affecting accuracy to five places of figures.

3. Nystrom's, given also in Molesworth's Pocket Book as "an

American plan."—This plan follows Willis in drawing a "fifteen degree line," but at the distance of the other side of the tooth or space, instead of the half pitch, from the pitch point; and the distance along that line is given by the formula :—

$$\text{Distance} = \cdot 11 \text{ pitch } \sqrt[3]{\text{No. of teeth}} \qquad (4)$$

to give the centre for the face arc.

This agrees with what is required fully as well as Willis's up to about 100 teeth, but beyond that it goes on indefinitely increasing the radius with the number of teeth; whereas, there is a limit which should not be passed, viz., the proper radius for a rack (which is just part of a wheel of an infinite number of teeth). The formula is only empirical, and the objection referred to is roughly avoided by saying that a wheel above 200 teeth is treated as a rack; it would be better at above 100 teeth.

The distance, outwards, along the 15° line, for the centre for the flank arc is given thus :—

$$\text{Distance} = \frac{\text{No. of teeth} + 6}{\text{No. of teeth} - 11} \times \text{pitch.} \qquad (5$$

This formula happens to agree very closely with the writer's principle. If it is the assumed thickness of tooth = ·45 of pitch, and rolling circle of $5\frac{1}{2}$ teeth, it agrees almost exactly. But this agreement is obviously accidental. Not to speak of the thickness of tooth varying in different cases, we have the direction of the centre determined by the 15° line, which is only adapted to the 6-tooth rolling circle. For the term — 11, in the formula, determines that the pinion of 11 teeth has the flank radius infinite, *i.e.*, the flanks are straight lines, and they ought to point to the centre of the pinion, according to the property of the epicycloid traced by a rolling circle equal to half the pitch circle, being simply a straight line through the centre. But the 15° line used makes these flanks diverge inside of radial lines about 3°. The flanks of pinions of 12 and 13 teeth, and so on, partake of the same error, rendering them all gratuitously weak at the root. (See N N, Plate XLIII.).

4. The "trial radius" plan. This consists in the draughtsman actually drawing the epicycloid curve, or at least finding a few points therein, by construction, in such a way as directed by Moleswortlı; or by having the rolling circle drawn on a piece of tracing paper, with a series of equidistant points laid off on it and on the pitch circle. Then by trial finding a radius and centre to suit the part of the curve required as well as possible.

In principle this method is just the right way. But practically—

1st. If the draughtsman trusts to Molesworth's construction (p. 202, new edition) nine persons out of ten will apply it wrongly (the language is so defective) by taking the distances "$d j = y d$," &c., as straight line distances, instead of measured on the curves as they should be. The effect of this erroneous construction is shown in Plates XLII. and XLIII. by curves marked O M. 2nd. Suppose the curve correctly constructed, the arc is usually so short that the proper radius can only be got very roughly; the direction of the centre may be found pretty well, but the length of radius may often be varied nearly 50 per cent. without the eye being able to say which point suits best. So much is this so that for small pitches it is found advantageous to draw the diagram to an enlarged scale. The writer, for some years, followed the plan of calculating the radius by formula (2) (having derived it from Rankine's Applied Mechanics), and then finding the direction of the centre by the above construction. And it was only when he tested the method on the scale of 10-inch pitch, that it became evident that the radii so found were always too great, and that something better should be obtainable.

Further investigation resulted in the obtaining of a principle on which tables could be calculated, by which both the length of radius and the position of centre would be got at once, for an arc of circle that would in all cases coincide with the true epicycloid curve in the best possible way.

PRINCIPLE OF THE NEW METHOD.

Let H = the height of curve required above or depth below the pitch line.

r = the radius of rolling circle,

m = the ratio of pitch circle to rolling circle, so that

$m\,r$ = the radius of pitch circle,

x = the divergence of the curve at the height H, from a radial line.

Then, by an approximate equation to the epicycloid (omitting details of mathematical demonstration), we have

$$x = \frac{\sqrt{2}}{3} \cdot \frac{H^{\frac{3}{2}}}{\sqrt{r}} \cdot \frac{m + 2}{\sqrt{m\,(m + 1)}} = \frac{m + 2}{3} \sqrt{\frac{2\,H^3}{r \cdot m\,(m + 1)}} \qquad (1)$$

By this equation we can also find the divergence from radius of any other point of the curve, say, at $\frac{H}{2}$; it is then $= \frac{x}{\sqrt{8}} = \cdot 354\,x \qquad (2)$

and, having now three points in the curve, we can find the radius and position of centre of the arc of circle passing through them.

This radius, R, is found $= \frac{\sqrt{Hr}}{\frac{4}{3}\sqrt{2} - 1} \cdot \frac{\sqrt{m(m+1)}}{m+2}$, for the face arc, $=$ practically to $1{\cdot}81 \sqrt{Hr} \cdot \frac{m + \frac{1}{2}}{m + 2}$ (3)

and for the flank arc the last factor becomes $\frac{m - \frac{1}{2}}{m - 2}$ (4)

so that in future the double sign $\pm$ will represent both.

The face arcs thus obtained are shown in Plates XLII. and XLIII. and marked O, C, *a*, *d*, *b*. They coincide with the epicycloid curve at the points O, *a*, *b*, and have a divergence inside at C, and outside at *d*, not more than one-fifth of that of Willis's at EW. Practically, the arc can be carried to a height beyond H, as to *e*, so that the divergence at *e* does not exceed that at *c* or *d*. This increased height is distinguished as *h*, $=$ from $1{\cdot}06$ to $1{\cdot}1$ H.

The position of centre is found to be at a uniform distance from the tangent at the pitch point.

This distance, $\Delta = \frac{H}{\sqrt{8}} = {\cdot}354$ H (5)

We may assume $\Delta = {\cdot}3\ h$, or $h = 3\ \Delta$; and then

$R = 1{\cdot}76 \sqrt{hr} \cdot \frac{m \pm \frac{1}{2}}{m \pm 2}$ (6)

or, independent of the exact *h* used, $R = 3{\cdot}045 \sqrt{\Delta\, r} \cdot \frac{m \pm \frac{1}{2}}{m \pm 2}$ (7)

This does not yet give the ratio of R, or of Δ to the pitch, because these vary with the rolling circle and the height of tooth assumed.

Of the three methods first described, of drawing an approximate arc by rule or table, none make any provision for difference of height of tooth, and Adcock only provides for three special rolling circles, viz., equal to 4, 5, and 6 teeth, without showing how to modify for others.

Now teeth are used at different heights, from Adcock's ·2 of pitch to about ·36 of pitch. (Higher teeth are met with; but usually only in the case of gearing for small rollers, &c., which have to vary in their distance of centres considerably.) The less the height of a tooth the stronger it is, and in cases where the greatest strength is wanted, while the wheels have only to move occasionally, there is no objection to having *h* as small as just to have one tooth taking hold before another lets go, *i.e.*, the "path of contact," M N, Plate XLIV., must be not less than the pitch; $h = {\cdot}25\ p$ is about the smallest convenient proportion.

But wheels that are working constantly, and it may be rapidly, for from 9 to 24 hours a day, require to provide for wear as much as possible. This makes it an object to have the teeth as high as is consistent with strength, and to have several teeth in contact at once if possible. This last condition is also favourable to smoothness of motion. The almost unanimous voice of practice seems to favour the proportion of $h =$ from ·3 to ·35 of pitch.

A large rolling circle increases the number of teeth in contact at once; and, giving a more vertical-sided tooth, diminishes the "push apart" thrust of the wheels. But it is usually a condition to have all the wheels of one pitch (and height of tooth) able to work correctly together, and for this they must all have the same rolling circle, and as the pinion of double the size of the rolling circle has straight radial flanks, it is usual to count that the smallest of a set, and 12 teeth is the largest number that can well be taken as the smallest of a set; corres ponding to 6 tooth rolling circle; but 4, 5, or 7 teeth may be preferred in different cases.

And there are special cases when the engineer will prefer to have his wheels to suit their own work independent of such a condition as working correctly with other wheels, and then he may use a rolling circle as large as he pleases up to one-half the size of each wheel for its own flanks (making them straight radial lines), and the other wheels' faces. Then equation (6) (p 275) gives the radii; and when h is fixed it may be written $R = A\sqrt{r}\,\dfrac{m \pm \frac{1}{2}}{m \pm 2}$ (8)

or putting t for No. of teeth in wheel.

n ,, ,, in rolling circle.

$$R = A\sqrt{r}\,\frac{t \pm \frac{n}{2}}{t \pm 2n} \qquad (9)$$

Where $A = 1 \cdot 76\sqrt{h}$, and has several values, given in Table I.

If the rolling circle for faces be made = half the wheel then

$$R = 1 \cdot 1 \times \sqrt{hr} = B\sqrt{r} \qquad (10)$$

r, h, and R being in any units and irrespective of pitch in all these equations; but if h be stated in terms of pitch, the pitch is the unit for r and R also.

For fixed rolling circles of n teeth :—

$$r = \frac{np}{2\pi} = \frac{np}{6{\cdot}28} \text{ and } p = \frac{6{\cdot}28r}{n} \qquad (11)$$

$$R = \cdot 7\sqrt{hn} \cdot \frac{t \pm \frac{n}{2}}{t \pm 2n} \cdot p \qquad (12)$$

$$\text{or } R = C\sqrt{h} \cdot \frac{t \pm \frac{n}{2}}{t \pm 2n} \cdot p = D\frac{t \pm \frac{n}{2}}{t \pm 2n} \cdot p = D\,E \cdot p$$

TABLE I.

VALUES OF A, B, C, D, E, IN THE ABOVE.

		Number of Teeth in Rolling Circle.					
		n	5	6	7	$\frac{t}{2}$	
$r =$		$\frac{np}{6·28}$	·796 p	·955 p	1·14 p	½ Radius of Wheel.	r
C =		·7 $\sqrt{n}$	1·57	1·72	1·855	B =	A =
$h =$	$\Delta =$	Values of D for same.				1·1$\sqrt{h}$	1·76$\sqrt{h}$
·25p	·083p	·35 $\sqrt{n}$	·785	·86	·927	·55	·88
·29p	·097p	·377$\sqrt{n}$	...	...	1·0*	·59	·945
·3 p	·1 p	·384$\sqrt{n}$	·86	·94	1·015	·60	·962
·34p	·113p	·41 $\sqrt{n}$	·91	1·0*	1·08	·64	1·03
$E = \frac{m \pm \frac{1}{2}}{m \pm 2} =$		$\frac{t \pm \frac{n}{2}}{t \pm 2n}$	$\frac{t \pm 2\frac{1}{2}}{t \pm 10}$	$\frac{t \pm 3}{t \pm 12}$	$\frac{t \pm 3\frac{1}{2}}{t \pm 14}$	$\frac{5}{8}$	

When the value of h, and rolling circle, are fixed on for a set of wheels, a table of the values of D E for different numbers of teeth can be made. The writer has prepared specimen Tables XLIII. and XLIV., for the cases marked * in Table I., where the co-efficient D becomes 1, as they are most easily calculated, and tables for other cases are easily derived from them by multiplying by the proper value of D.

The radii thus given will suit practically well enough for values of h, varying from 2·9 to 3·1 times the value of Δ in the table, if that Δ be adhered to. But if h be wanted further altered, in a particular case, the table may still be utilized by altering R in half the ratio that h is altered, and making $\Delta = \frac{1}{3}$ the new h.

The cases shown in Plates XLII., XLIII., and XLIV. are all to rolling circle of 6 teeth, and $h = ·34\,p$. It will be at once seen how much closer the approximation to the epicycloid curve is than by the other methods; also that the angle with radial line at pitch point is much less. It may be observed that the approximation obtained is better

the larger the rolling circle,
the smaller h is,
the greater the number of teeth for faces,
the smaller the number of teeth for flanks.

Taking the worst case shown in Plate LXIII., the maximum divergence at the points *c*, *d*, *e*, is only $\frac{1}{350}$ of pitch, while Willis's is $\frac{1}{70}$, or 5 times; and an arc drawn by the above rules, for $h = \cdot 2$, Adcock's height, would have only $\frac{1}{7}$ of his divergence.

In passing from this small pinion to larger numbers of teeth, and to a straight rack, the divergences diminish to about one-half the above. The rack's face and flank are alike; and in passing again to a small pinion the flank arc approaches more and more to a straight line, and the divergences referred to also get less till at the pinion of straight flanks they disappear. The tabular R at this point becomes infinite; and if formula (12) be used to find flank radius for a less number of teeth, it gives a negative quantity, as shown in Table II., at 11 teeth. This means that the radius is turned the other way, in same direction as the face radius (but with centre outside the tangent as usual), and the flank is convex, turned inwards from the radial line. Of course this, *per se*, is a weak form, but when flanged or capped as such pinions usually are, they can be made as strong as others; so that such pinions can be made use of down to the point at which the path of contact M N (Plate XLIV.) becomes no more than the pitch.

Plates XLIV. and XLV. show the comparative accuracy of working of the new and old methods; the working sides of a pair of teeth in contact being shown in successive stages of progress of one-sixth of the pitch; the pitch lines being supposed to advance uniformly in both cases. It will be seen that the "new method" teeth keep contact almost perfectly, while Willis' teeth fail to do so after the first stage on each side of pitch point.

While this is conclusive as to the superiority of the new over the old approximate methods, it may be objected, why not use the epicycloid arcs themselves, are they not best of all? They certainly are. And wherever teeth of wheels are actually made so, by a rolling circle template applied to outside and inside templates of the pitch circles, and the model tooth so found accurately copied in all the teeth, there the method described becomes unnecessary.

But the trouble involved in making four templates (besides rolling circle one) for every fresh pair of wheels, and the skill necessary to use them rightly, are such that in general circular arcs are still preferred.

If preferred, the divergence of the centres for the face and flank arcs from the *pitch line* instead of from the tangent, can be used and inserted in the tables; or in all cases except the flanks of small pinions it may be got by the rule,

$$\text{Divergence from pitch line} = h\left(\tfrac{1}{3} \mp 1{\cdot}55\,\frac{m+1}{(m+2)^2}\right) \qquad (13)$$

The $-$ for the face and $+$ for the flank.

The following part of the paper is equally applicable, whether the exact epicycloid curves are used or an approximate method.

THE WORKING OR CONTACT PART OF THE FLANK.

This is never equal to h, rarely four-fifths of it. It is shown in Plate XLIV. thus. The parts of the rolling circles which pass where the teeth are in contact are the theoretical "path of contact," M O N (exactly for epicycloid teeth, and approximately observed by the approximate teeth). Its ends are fixed by the points M N, where each rolling circle passes outside the circle of the points of the teeth of the other wheel. In the case shown, from M to pitch line of rack $= {\cdot}72\,h$, and from N to pitch line of pinion ${\cdot}53\,h$, it is less as the Nos. of teeth are less, and least in the smallest of the two wheels. It is called the "contact depth" in the tables. Its defect from h varies almost exactly as $\frac{1}{t} + \frac{1}{t_{\prime}}$ the sum of the reciprocals of the Nos. of teeth. It is rare to have spur wheels gearing together, so that $\frac{1}{t} + \frac{1}{t_{\prime}}$ is less than ${\cdot}04$, *i.e.*, it is rare to have equal wheels of more than about 50 teeth, or a rack with a pinion of more than 25 teeth (except in change wheels of lathes, &c.).

The part of the flank below this "contact depth" does not need to follow the curve as already found; and, if desirable for strength, it may be swelled out to any shape that will clear the corner of the other tooth. In the case of small wheels or "pinions" this is desirable, and as the contact depth is least in them, there are the means of strengthening the teeth considerably where most required. The tooth of pinion in Plate XLIV. shows one way of doing this; and Table II. has columns showing how this "contact depth" varies for an assumed value of $\frac{1}{t} + \frac{1}{t_{\prime}}$ and the extreme size of wheel that each wheel will work with correspondingly. Another column gives the smallest wheel that each will work with without the path of contact becoming too small.

THE PITCH OF TEETH.

It was mentioned that Adcock's tables assumed the pitch to be the straight line distance between pitch points, so as to make the diameter of pitch circle greater than by the exact rule,

$$\text{Diameter} = \frac{\text{No. of teeth} \times \text{pitch}}{3{\cdot}1416}, \text{ especially with small pinions.}$$

Adcock is not alone in this. A similar table of diameters to suit "polygonal" pitch is given in Lockwood's Weale's Pocket-Book, and one in the last edition of Molesworth's. Nystrom also introduces the same idea, mixing up rules on both principles.

Still the author cannot understand how any one should retain this idea alongside of the fundamental principle that accurate working requires that the teeth act together precisely as if the pitch circles *rolled continuously* on each other without slipping.

But, assuming that the circumferential pitch is always equal, then the straight line pitch, which the draughtsman or pattern-maker takes in his compasses, is less; and in small pinions sensibly less. And for drawing teeth, when only a part of the circle is wanted, it is useful to find the exact size without having to draw the whole circle to divide it.

$$\text{This "deduction from pitch"} = \frac{\pi^2}{6t^2}p = \frac{1{\cdot}645\,p}{t^2} \qquad (14)$$

It is shown in a column of Table II., up to 40 teeth, when it is only $\frac{1}{1000}p$, while at 20 teeth it is four times, and at 10 teeth 16 times as much; varying inversely as the square of the number of teeth.

BEVEL WHEELS (INCLUDING MITRE WHEELS).—SIZE OF ROLLING CIRCLE.

Bevel wheels differ from spur wheels, in what affects the forms of the teeth, in three respects.

1.—If teeth be made with any needless amount of slope or angle away from the radial line through pitch point, the resulting pressure tending to push the pitch lines apart is particularly objectionable, as it introduces angular and lateral pressures on wheels, bearings, and framework, and end wear on bearings; hence, to have a large rolling circle is desirable.

2.—The special object of bevel wheels being to change the direction of motion, it is usually not so much an object to get change of velocity thereby, and small pinions are certainly less employed than in spur gear. The difficulties of suitable point bearings and extreme lateral pressures also discourage the use of such pinions. Hence, a large rolling circle is more admissible; and the more so from the consideration under the head "Virtual numbers of teeth."

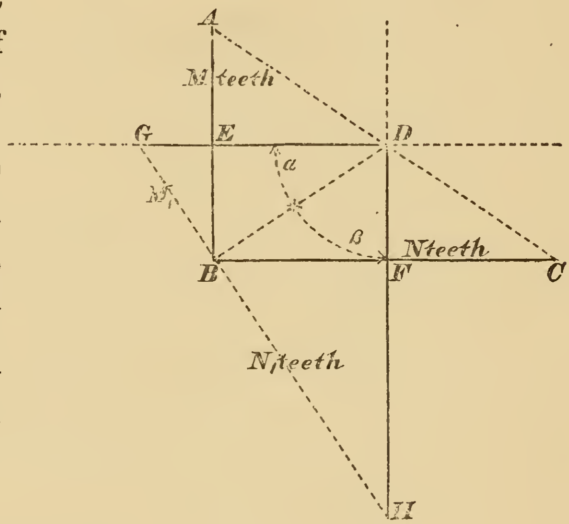
3.—It is not usually made a condition that bevel wheels be able to work correctly with any others of the same pitch besides their own fellows.

Hence, when this last is the case, a rolling circle may be used up to half the virtual number of teeth of each wheel, for its own flanks and the other wheels' faces.

And if they are wished to work with other wheels (as afterwards described) the rolling circle may still be kept about double of that for spur wheels. This will require separate tables for R and R, from those for spur wheels.

VIRTUAL NUMBERS OF TEETH AND RADII OF WHEELS.

The number of teeth, or the factor m, to be used in the formulæ, or to go into the tables, is not the real number of teeth, nor the real radius of wheel ÷ radius rolling circle, but is to be found thus:—



Let the lines A B and B C be the diameters of a pair of bevel wheels, seen in edge view, and D G, D H, the centre lines of their shafts. Draw also B D and G H at right angles to B D.

Then, for the forms of teeth, the "virtual radius" of wheel A B is B G, $= \text{B E}\,\frac{\text{B D}}{\text{D E}}$, and of wheel B C is B H $= \text{B F}\,\frac{\text{B D}}{\text{D F}}$.

The "virtual" m is the $\frac{\text{virtual radius}}{r}$.

The "virtual number of teeth," always greater than the real number, is $M_1 = M\,\frac{\text{B D}}{\text{D E}}$ and $N_1 = N\,\frac{\text{B D}}{\text{D F}}$.

CAPABILITY OF WORKING WITH OTHER BEVEL WHEELS.

Although each pair of bevel wheels is usually designed to work only with each other, and that at right angles; yet, if there be any two pairs of bevel wheels of same pitch, having the dimension B D the same (and of same rolling circle and h), then any of the wheels will work with any of the others; of course at angles determined by the angles a and β in each case.

It may be said that cases where this is done are rare; but it is sometimes wanted, and would likely be much oftener resorted to, if facilities were afforded for obtaining wheels to suit.

Now, in arranging sets of bevel wheel patterns, or deciding on exact size for a pair for a given purpose, it would be a simple matter, when other conditions did not prevent, to prefer such sizes as would produce series of wheels of the same "conical" radius B D.

The sum of the squares of the numbers of teeth in any pair of such a series will equal that of any other pair (a difference of 2 or 3 will be immaterial) and will be more easily calculated than the length of B D itself, as the radii B E, B F, are usually fractional numbers. Let the square root of this "sum of squares" of M and N = T.

Then $M_1 = M \frac{T}{N}$ and $N_1 = N \frac{T}{M}$

TABLE IV.

EXAMPLES OF SUCH SERIES OF "INTERCHANGEABLE" BEVEL WHEELS, WITH THEIR ANGLES α AND β, AND VIRTUAL NOS. OF TEETH.

Conical radius = 7·96 *p*. T = 50. $M^2 + N^2 = 2500$.						Conical radius = 11·94 *p*. T = 75. $M^2 + N^2 = 5625$.					
M	M_1	α	N	N_1	β	M	M_1	α	N	N_1	β
*14	14·6	16·3°	48	171	73·7°	*17	17·2	13·1°	73	322	76·9°
17	18·1	19·9°	47	138	70·1°	21	21·9	16·3°	72	257	73·7°
20	21·7	23·5°	46	115	66·5°	27	29·	...	70	194	
22	24·4	26°	45	102	64°	32	35·2	...	68	160	
24	27·3	28·5°	44	92	61·5°	36	41·	28·6°	66	137	61·4°
27	32·1	32·8°	42	73	57·2°	39	45·	...	64	123	
*30	37·5	36·9°	40	66·6	53·1°	42	51·	...	62	111	
31	39·2	38·5°	39	63	51·5°	*45	56·2	36·9°	60	100	53·1°
32	42·1	40°	38	59	50°	48	62·	...	58	91	
33	45·1	41·8°	37	56	48·2°	50	67·	...	56	84	
34	47·2	43·4°	36	53	46·6°	52	72·	...	54	78	
35	50·	45° or Mitre Wheel.				53	75·	45° or Mitre Wheel.			

Only a few pairs in such a series as those marked * can be exactly of the "conical radius" mentioned; but the others, though a little less or more, are practically near enough.

When bevel wheels are designed, let the conical radius B D, and angles α and β, be marked on the plan; and in the list of wheels let columns be given for them. Let these columns be inserted also in the published lists. Then whenever a pair are wanted to work at any special angle, it will be a simple matter to find out from those of same conical radius if there are any whose ratio and angles will suit, instead of having to draw them as at present.

TABLE II.

Radii for Faces and Flanks of Teeth in the case of Rolling Circle = 6 Teeth, $h = {\cdot}34\ p$ and $\Delta = {\cdot}113\ p$.

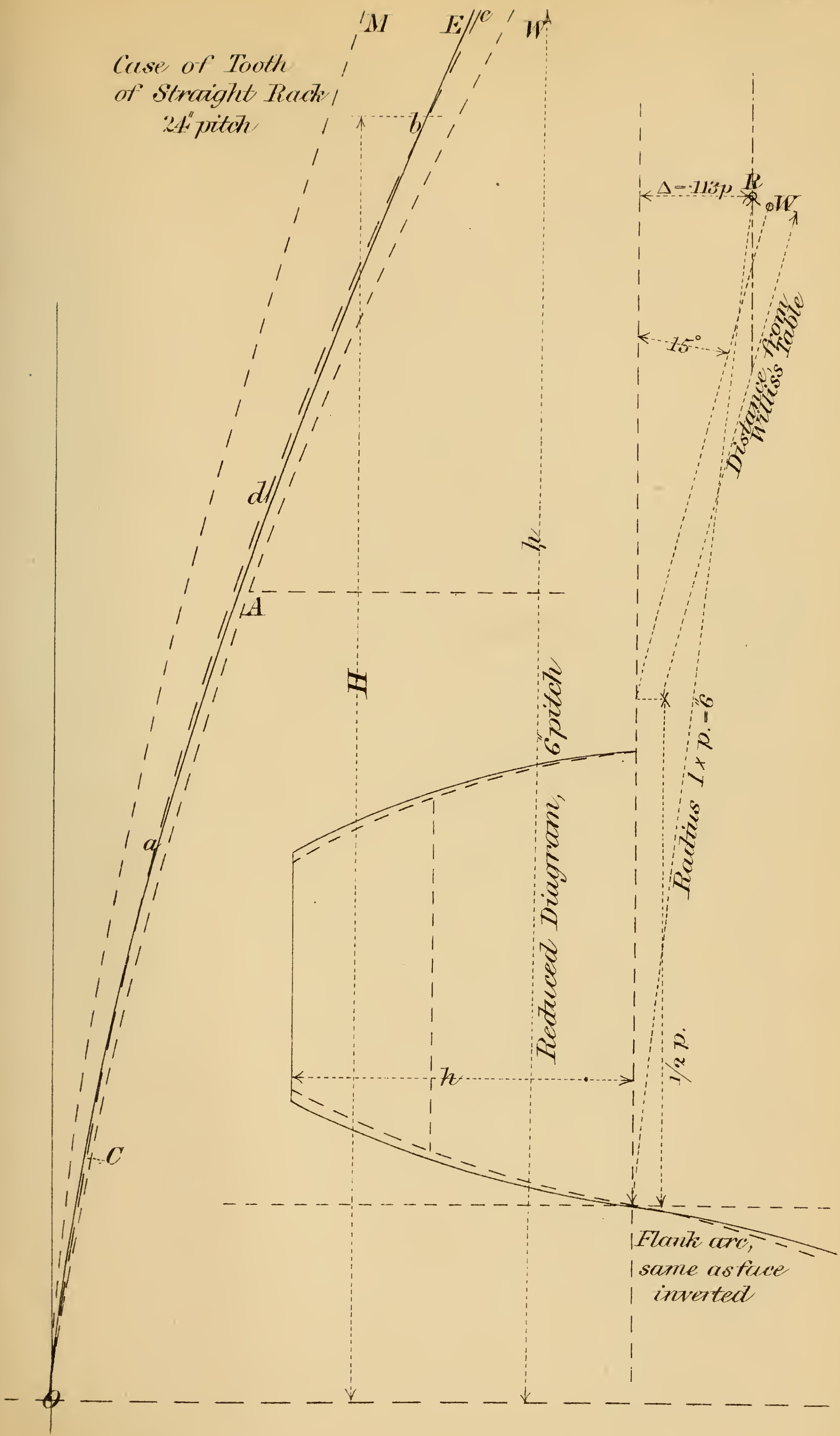
Deduction from Pitch.	No. of Teeth	Radius for		Contact Depth.	Works with Teeth.	Deduction from Pitch.	No. of Teeth.	Radius for		Contact Depth.	Works with Teeth.
		Face.	Flank.					Face.	Flank.		
$p\times$		$p\times$	$p\times$	$h\times$	Internal	$p\times$		$p\times$	$p\times$	$h\times$	External
·0136	11	·6	—7·7	·6	35	·0020	28	·77	1·56	·79	
·0114	12	·62	Infinite	·64	40	·0018	30	·785	1·5	...	120
·0097	13	·636	9·8	·66	45	·0015	33	·8	1·42	·8	90
·0084	14	·65	5·4	·68	50	·0013	36	·81	1·37	...	72
·0073	15	·664	3·95	·7	56	·0011	39	·82	1·33	...	62
·0065	16	·676	3·22	·72	64	·0010	42	·83	1·3	·81	56
·0057	17	·687	2·77		76		48	·85	1·25	...	48
·0051	18	·697	2·48	·74	90		52	·86	1·22		
·0045	19	·706	2·27	·75	104		57	·87	1·2	·82	
·0041	20	·715	2·11	·76	120		60	·875	1·187		
·0037	21	·723	1·99	·77	140		72	·88·	1·15		
·0034	22	·731	1·89		270		80	·9	1·14		
·0031	23	·74	1·81	·78			100	·92	1·1	·83	
·0028	24	·75	1·74	...	Rack		140	·94	1·07		
·0026	25	·756	1·69	·79			210	·96	1·04		
·0024	26	·761	1·64	...	External		420	·98	1·02	·84	
·0022	27	·767	1·6	...	300		Rack	1·00	1·00		

TABLE III.

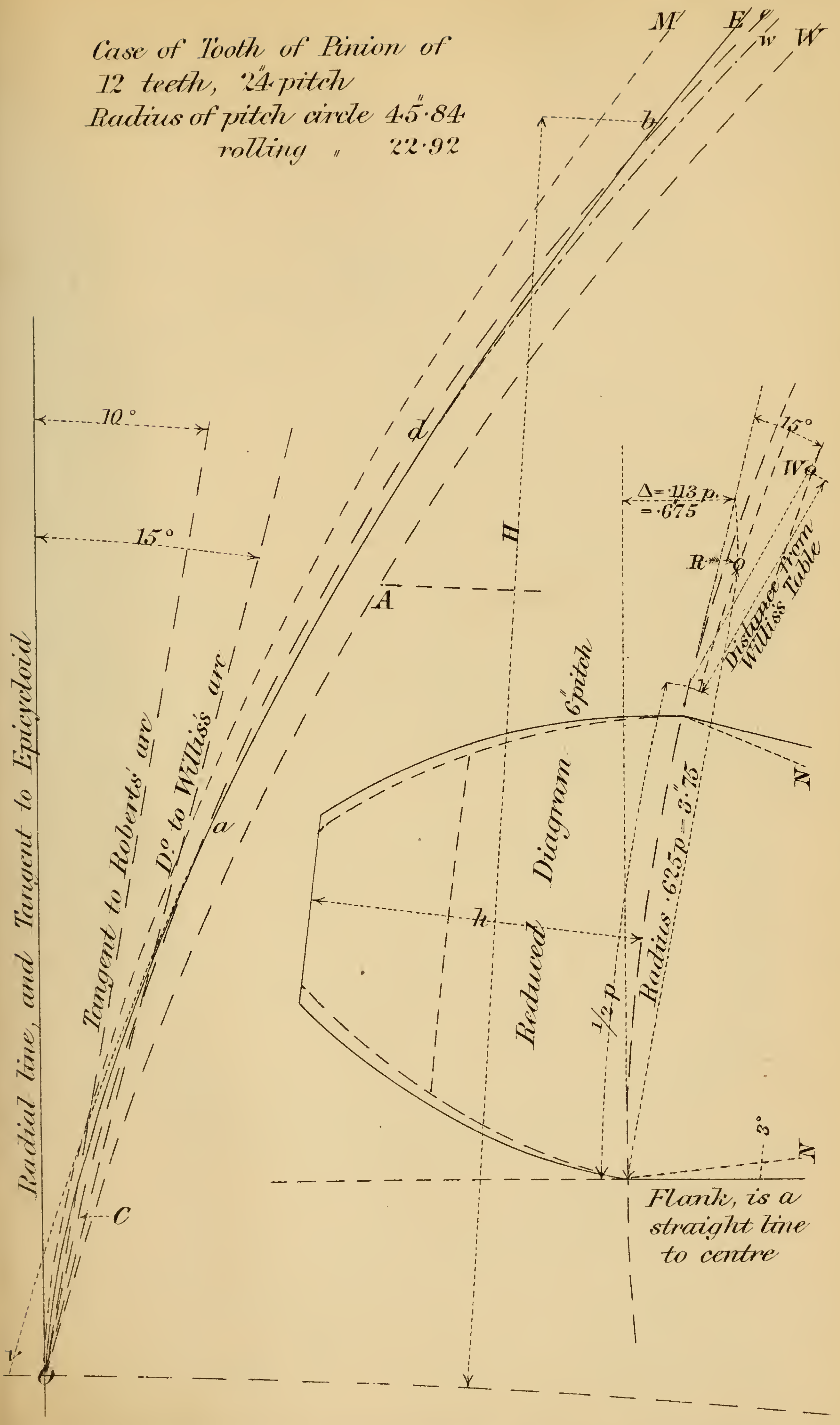
RADII FOR FACES AND FLANKS OF TEETH IN THE CASE OF ROLLING CIRCLE $= 7$ TEETH, $h = \cdot 29\ p$ AND $\Delta = \cdot 97\ p$.

No. of Teeth.	Radius for		No. of Teeth.	Radius for		No. of Teeth.	Radius for	
	Face.	Flank.		Face.	Flank.		Face.	Flank.
12	·59 p	—4 p	25	·728 p	1·95 p	62	·86 p	1·22 p
13	·605	—9·2	26	·735	1·87	67	·87	1·2
14	·62	Infinite	27	·743	1·8	74	·88	1·17
15	·635	11·0	28	·75	1·74	80	·89	1·15
16	·65	6·1	30	·76	1·66·	91	·9	1·135
17	·66	4·4	32	·77	1·6	103	·91	1·12
18	·67	3·6	35	·785	1·5	118	·92	1·1
19	·68	3·06	38	·8	1·44	137	·93	1·085
20	·69	2·72	42	·81	1·375	162	·94	1·07
21	·7	2·48	45	·82	1·33·	196	·95	1·06
22	·706	2·25	48	·83	1·3	250	·96	1·042
23	·713	2·13	52	·84	1·27	500	·98	1·02
24	·72	2·03	57	·85	1·25	Rack	1·00	1·00

Mr. THOS. ADAMS then read a paper "On a New form of Direct-acting Spring Safety-valve."



And^w Reid, Newcastle



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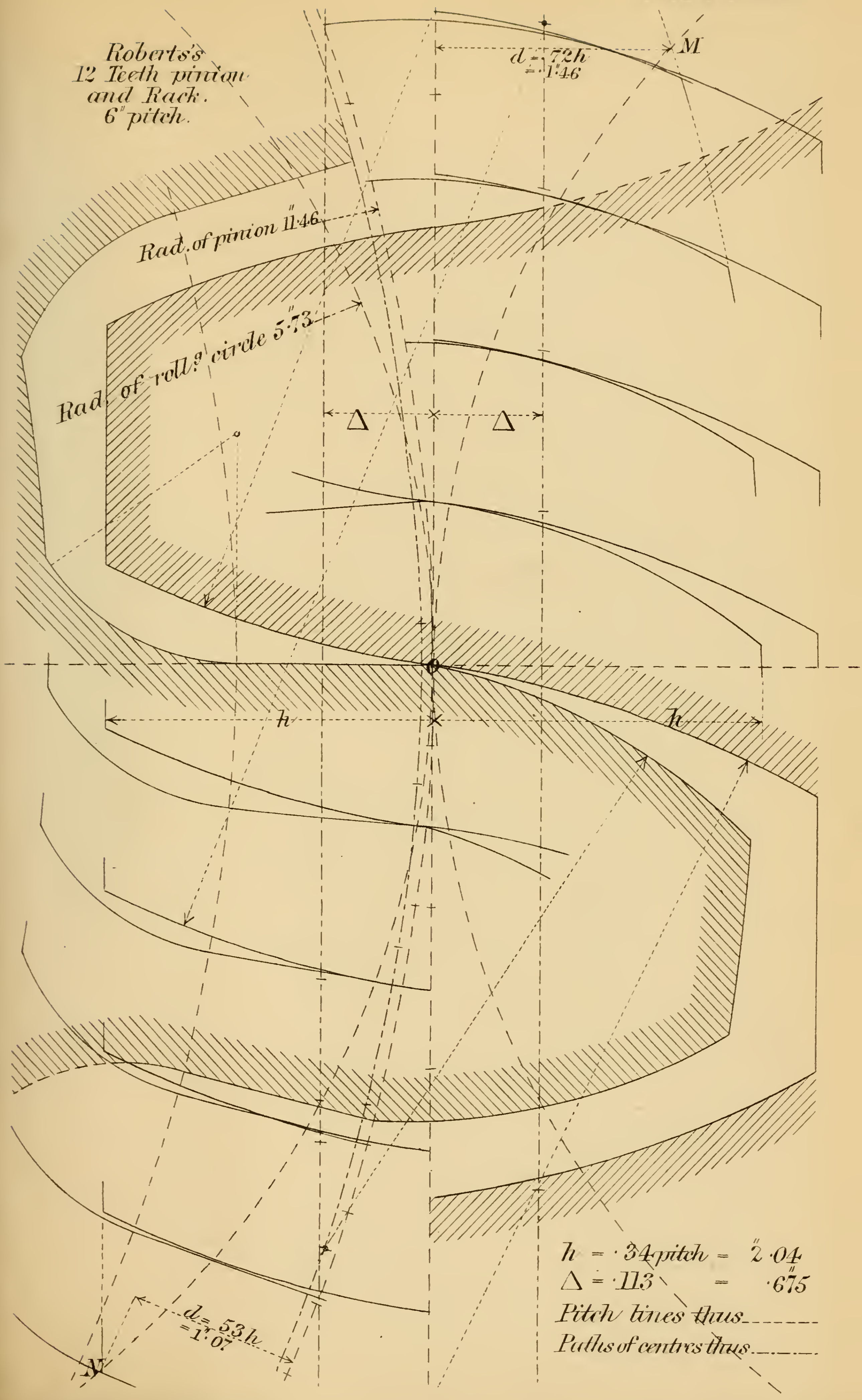

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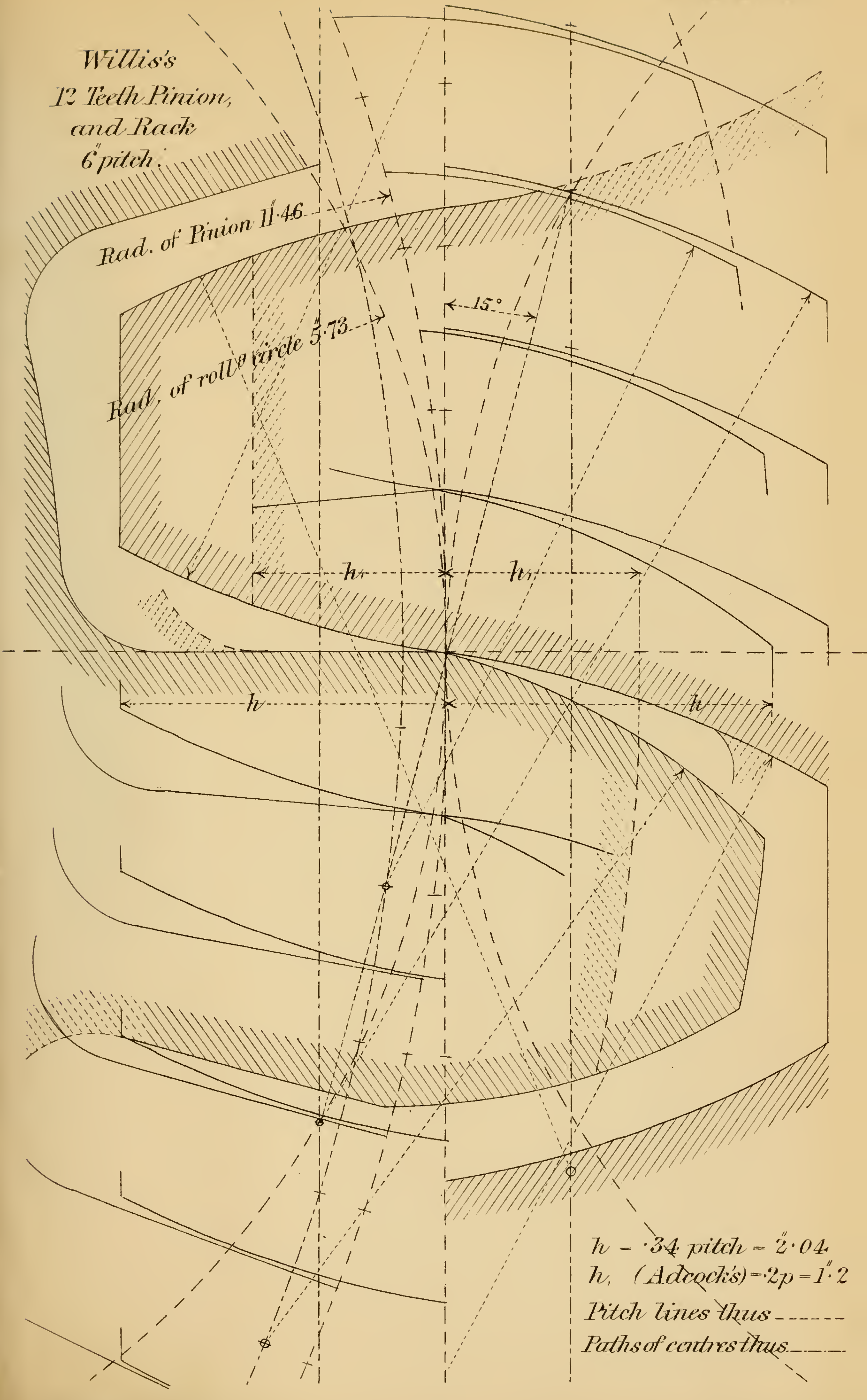

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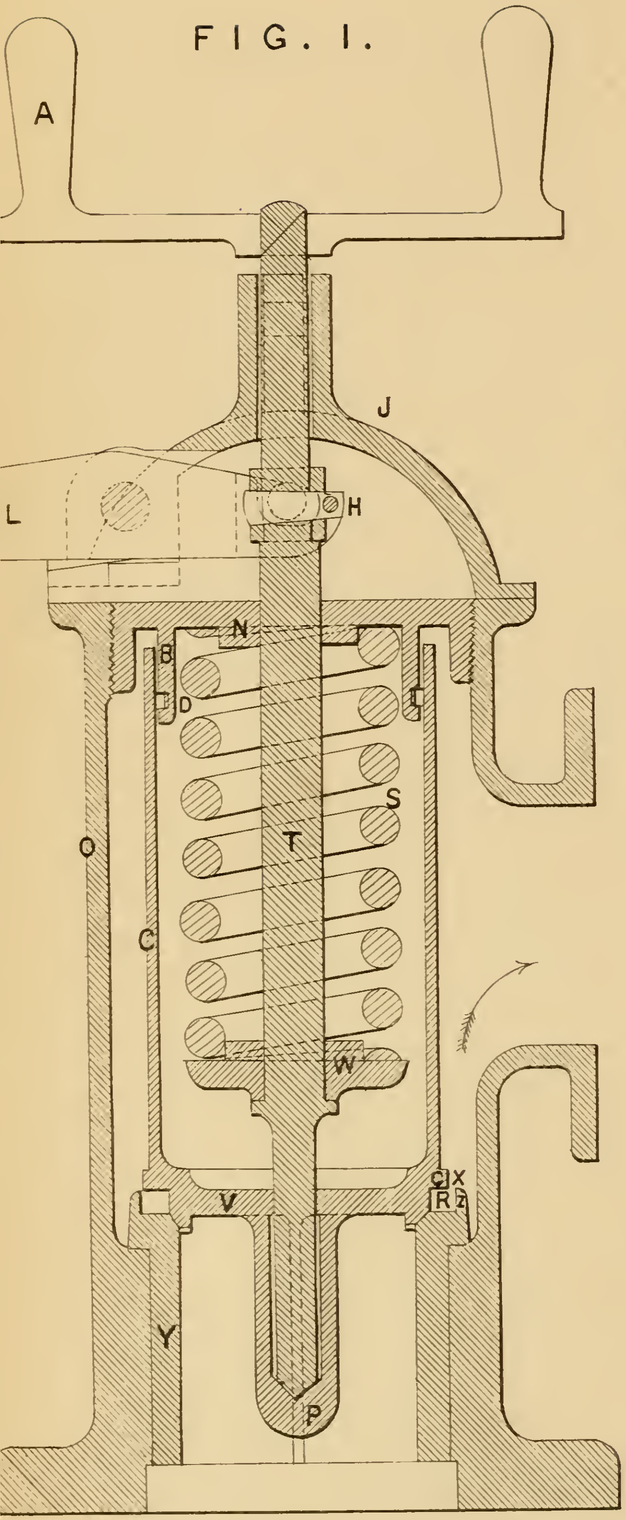
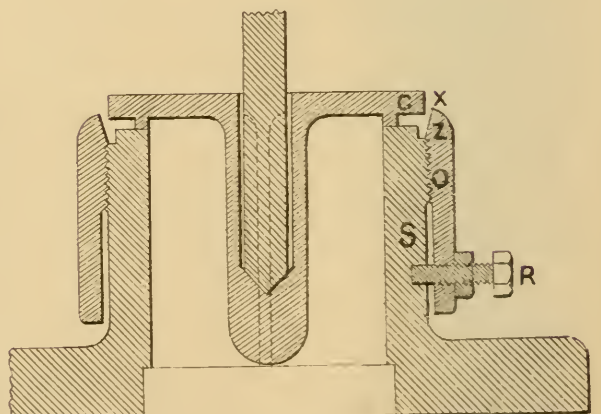
FIG. 1.



Drawing illustrating Mr. Thomas Adams' Paper on a new form of Direct acting Spring Safety Valve.

FIG. 2.



ON A NEW FORM OF DIRECT-ACTING SPRING SAFETY-VALVE.

BY THOMAS ADAMS.

For some time past considerable inconvenience has been felt by the marine engineer from the unpractical nature of the rules and regulations of the Board of Trade, which give half a square inch of area of safety-valve for every square foot of grate. This rule gives a very large amount of dead weight to balance the 80 lbs. internal pressure now universally used afloat, and also contains an erroneous element of calculation, since the relieving power of the valve is directly, as its diameter, multiplied into the cosine of the angle of lift measured from the horizontal line of valve face and by the relative volume. But as the velocity of the issuing jet at the orifice of the valve bears a relative proportion to the relative volume, the density and the pressure, it follows that only one of those elements need enter into the calculations of the proportions of safety-valves, and the writer prefers taking the relative volume.

The Board of Trade, alive to the necessity of making improvements in safety-valves, has offered a reward of £100 for the best design of a spring safety-valve; the spring to be protected from the action of steam or sea water, and in case of breaking the valve to be protected from flying away, to have facilities for easing, &c., and to be locked up. And a Committee of the Institution of Engineers and Shipbuilders of Scotland, under their late President, Mr. David Rowan, are now making experiments upon safety-valves, and have had the good fortune to secure the aid of that most distinguished mechanic, Professor W. J. Maquome Rankine, in making the requisite deductions.

The writer now describes the valve he proposes to use. Plate XLVI., figure 1, shows a direct-acting spring safety-valve, as applied to marine boilers, where V is the valve and S the spring; C is a casing cast with V, which surrounds the spring; N is a nut with which to put force on the spring, having a cylindrical part B built on it and fitting inside of casing

C; D is a small packing ring fitted into B and pressing gently against the shell C for the purpose of preventing the waste steam from acting on the spring; W is a washer on which the spring rests; T is a steel spindle holding the valve to its seat, square inside the boss P for turning the valve with, but round in the point for bearing; H is a cross-head, under which the lever L acts, for the purpose of easing the valve or for blowing off, but no weight can be put on the valve by it, for if lifted up it leaves the cross-head; Y is the seating of the valve; A is a double handle, balanced, to turn the valve round on its seat in case of dirt getting between the faces; J is a cap covering nut N; R is an excess of space in which the steam is partially confined after it escapes through the seat, in order that it may act more directly on the lower face of C, and thus overcome increased resistance of the spring after the valve rises from its seat.

The main novelties in the valve are the area of concentric space R, and the mode of exposing the face C to a given pressure; the height of the edge Z, above the edge C, and the width of the orifice X. These improvements cause this valve to rise at the appointed pressure, relieve the boiler, and return to its seat again in a few seconds of time.

Plate XLVI., figure 2, is the method adopted for getting at the proper amount of extra area necessary to overcome the increased resistance of the spring. O is a round nut screwed on to the seating S, by which the top edges Z may be raised or lowered above the lower edge C of the valve, thus widening or narrowing the orifice X, until the proper proportion is ascertained. It may be admitted that a good safety-valve should, 1st, under no conditions whatever permit a pressure to generate within the boiler greater than that represented by the load placed on the valve; 2nd, that it should return to its seat with the least loss of internal pressure below that represented by the load on the valve; 3rd, that it should perform its duty in the least possible amount of time; and it is urged by the writer, that the valve now described fully satisfies all these conditions.

In the evening a large party of the members and their visitors dined together in the Banquetting Hall of Sir W. G. Armstrong at Jesmond.

PROCEEDINGS.

ANNUAL MEETING, SATURDAY, AUGUST 3, 1872, IN THE WOOD MEMORIAL HALL.

WILLIAM COCHRANE, Esq., in the Chair.

The election of officers for the ensuing year was proceeded with. Messrs. A. L. Steavenson, J. Bailes, Jun., J. B. Atkinson, and E. Hague were appointed scrutineers of the voting papers.

The Secretary read the minutes of the last meeting, which were confirmed and signed, also the report of the Council and the report of the Finance Committee, which, on the motion of the Chairman, were unanimously agreed to.

The following gentlemen were nominated for election :—

Members—

Mr. Hugh Andrews, Coal Owner, Eastfield Hall, Warkworth.
Mr. C. T. Maling, Ford Pottery, Newcastle-on-Tyne.
Mr. William Refeen, Coal Owner, Teplitz, Bohemia.
Mr. J. G. Kimpton, 40, St. Mary Gate, Derby.
Mr. Richard Forster, Coal Owner, White House, Gateshead.
Mr. Grainger Heslop, Whitwell Colliery, County of Durham.
Mr. James Cope, Port Vale, Longport, Staffordshire.

Student—

Mr. Alfred Winter Barnes, East Hetton, Coxhoe.

The Chairman thought they would be glad to hear that their late

President, who that day resigned his post, was progressing as satisfactorily as could be desired after the late painful operation which he had undergone in London. Very few people knew the anxiety which his family had about him when he came down here to attend their last meeting, and what a dangerous operation was imminent. But he had passed most successfully through it, and the latest information about him was highly satisfactory. It was hoped that he would be able to leave London in the course of a few days to come home again. With respect to the reprinting of certain of their volumes, referred to in the minutes of the Council, Mr. Reid's offer was, without colours, £137 for vol. 3, £136 for vol. 4, and £168 for vol. 5; 250 copies of each unbound. The number of applications made during the last six or seven years for these volumes had been very great; and the printer believed that there would be a very ready sale. They were all valuable, and they were especially valuable for those who had not and could not get them to make up their sets; and, therefore, it had occurred to the society that it was desirable to reprint them.

Mr. R. S. Newall thought it a matter of very great importance to the Society that the illustrations in the Transactions, if reprinted, should be the same as in the original volumes. Of course, if uncoloured, they did not convey to the reader so easily and so satisfactorily the information which he desired; and, therefore, although it was a considerable addition to the cost, he would be glad to move that they be reprinted the same as the original; that was, using colours for the illustrations.

Mr. I. Lowthian Bell—If Mr. Newall's suggestion be agreed to, the cost of the three volumes would be £650. From that sum they would have to deduct the number of the volumes sold; but it was a very large question, and he would rather hesitate in involving the Institute in so large a transaction at so small a meeting.

The Chairman was quite of Mr. Bell's opinion. He thought it would be better to postpone the matter until the next general meeting.

Mr. Bell said they must remember that it was not an expenditure which they were going to incur in order to promote the well-being of the Society as it was; it was for the new members entirely. He thought with Mr. Newall that if it was to be done at all, the proper way was to do it well. Either do it well or not at all.

Mr. Newall withdrew his motion.

The matter stands over for consideration at a future meeting.

PROPOSED INCORPORATION.

The Chairman read the following letter from Geo. Elliot, Esq., M.P. :—

23, Great George Street, Westminster, London, S.W.,
2nd July, 1872.

T. W. Bunning, Esq., Newcastle-on-Tyne.

Dear Sir,—I regret that, owing to my having to move and support this evening in the House of Commons several important amendments to the now pending Mines Regulation Bill, I shall be unable to have the pleasure of dining with the Members of the Institute to-morrow. I regret this very much, as I had intended to confer with some of the members on the subject of several of the provisions of the Mines Bill, which will materially affect the prospects of Mining Engineers. I refer to those clauses which provide that in future the responsible Managers of Mines shall pass an examination in Mining Engineering, and shall not be allowed to exercise their profession unless they hold a certificate of competency.

If you will refer to my inaugural address, when I had the honour of being nominated your President, you will find that I strongly advocated the co-operation of the Institute with the Institution of Civil Engineers, "a body possessing a Royal Charter "and other privileges, and having the power of conferring various degrees of profes- "sional rank upon those obtaining its certificate." I would suggest that the Council and members generally should consider the desirability of applying for some such Charter as that possessed by the Institute of Civil Engineers, and under which they would grant certificates of competency to precede, and probably, in time, to supercede the certificates now to be granted under the provisions of the Mines Bill. I regret that I have not the opportunity at present of explaining my views more fully, but if you will kindly give our worthy President and Council a hint of what I was about to propose, they will probably consider the question in all its bearings.

It is quite certain that the Mining Engineer of the future will have to act under entirely new conditions, and the question of how this altered state of things can be best turned to account, for his and the public benefit, cannot be too soon dealt with by the Institute, which has at heart the welfare of the Mining Engineer, and the progress of Mining Science.

I am, dear Sir, yours truly,

GEORGE ELLIOT.

In consequence of that letter, the Council asked the Secretary to see Col. Manby, the Hon. Secretary of the Institute of Civil Engineers in London, to explain fully what this Royal Charter meant, what process had to be gone through to get it, and what advantages were derived from it. He should also tell them that Mr. Newall and himself were appointed a committee some time ago to wait upon Mr. Dees with respect to the subject of incorporation, and Mr. Dees found insuperable difficulties at the moment in entertaining the question, or recommending them any course to adopt. But he waited upon Mr. Dees only ten days ago, and that gentleman stated there was an Act under which he thinks he will be able to deal with it, and to carry out the wishes originally expressed by the Institute something like six months ago. Therefore, all was in abeyance, and he thought that with the permission of the meeting, the matter had better be postponed until they got Mr. Dees' information upon the subject; and in the meantime they would get all the information they could from the Civil Engineers, and then they could consider it again.

Mr. J. J. Coleman, F.C.S., read a paper "On Mineral Oil as a Lubricant for Machinery."

MINERAL OIL AS A LUBRICANT FOR MACHINERY.

By J. J. COLEMAN, F.C.S.

The attainment of a good, efficient lubricating oil for machinery, of constant quality and cheapness, has always been an important and difficult object amongst machinists.

From time to time engineers have fixed upon special oils as being suitable for their purposes. Increased demand for such favourite oils has then caused prices to advance to far more than can be afforded.

This occurred with lard oil, which, once a favourite oil, reached and maintained for a long time a value of about £70 per ton; but a still better example is afforded by sperm oil, which attained and kept for some time a value of twenty-one shillings per gallon. The majority of the railway companies use rape oil; the Franco-Prussian war threw up the price of this article about 40 per cent.

The ever-increasing demand for lubricating oils, owing to extension of works, railways, and engineering operations, renders it more difficult every year to supply, economically, the requisite quantity of oil.

Most engineers are familiar, to some extent, with mineral oil; some condemn it in toto, and unreasonably; others like it.

The importance of the matter is, however, evident from the fact, that in the United Kingdom there is material and plant in existence for making annually about ten thousand tons.

Mineral oil has one great advantage, that it is not liable to absorb oxygen and cause gumming. The progress of science has latterly enabled it to be produced quite as free from smell as any oil in existence, and in colour equal to finest refined seed oils.

Mineral oil has, however, little body or viscidity. A vessel filled with mineral oil, having a fine pointed aperture from which the oil can run out, empties itself in about one-third the time that would be noticed in case of rape or olive oil being put in similar apparatus.

This very quality of thinness caused it to be noticed by the cotton spinners some twenty years ago. Mr. James Young conceived the idea, that mixing mineral oil with rape or lard oil would result in a product as near resembling sperm oil as possible.

Sperm oil is a peculiar oil as regards body, not so thick as other oils, but having more body than pure mineral oil.

Hence if any thick bodied oil like rape, olive, or lard oil is mixed in proper proportions with mineral oil, a product is obtained having exactly the consistency of sperm oil.

Each class of machinery requires meeting specially. An oil that will suit spindles will be so thin as to squeeze out of the bearings of heavier machinery. An oil suitable for an engine will rather retard than facilitate the motion of a spindle.

It was in consequence of this peculiar requirement that sperm oil was formerly the only oil cotton spinners used, but latterly for many years the majority of spindles have been run with mineral oil—in probably 75 per cent. of the mills in the United Kingdom. For the purposes of light machinery mineral oil is now established as a most valuable article of commerce.

About three years since the writer's attention was directed to the possibility of further extending the use of mineral oil for heavier machinery, particularly railway purposes, and through the courtesy of the locomotive superintendent of one of our principal Scotch railway companies an engine was placed at his disposal for experimental enquiries.

A great number of journeys were made between Glasgow and Edinburgh and Carlisle and Edinburgh—the point observed being to take the temperature of the axle box with each oil and the temperature of the atmosphere at the end of the journey, and (if not an express train) at certain points on the road.

The object was to find whether any mixture of pure mineral oil with ordinary fatty oils, such as rape, olive, or castor, would answer the purpose.

Mixtures containing 40 per cent. of mineral oil would not do at all; 30 per cent. produced occasional heating; 20 per cent. was passable. The general impression formed in the writer's mind at the time was that no mere mixture of mineral oil with other oils gives a resultant having sufficient body.

Mr. Jno. Orr Ewing, at whose suggestion the experiments were made, came to the conclusion, with the writer, that there ought to be a method of imparting chemically the requisite body to pure mineral oil.

Ordinary oils are compounds of fat acid and glycerine. Why not make mineral oil a compound oil?

After a time it was found that, by the use of a small proportion ot natural solid hydrocarbon, the body of the pure mineral oil could be increased so as fully to equal that of the best rape. With this new product, which is patented under the name of Mr. Jno. Orr Ewing and that of the writer, experiments were resumed on the locomotive engines. About twelve express train journeys were made between Glasgow and Edinburgh and Carlisle and Edinburgh. The gain of temperature per mile with rape oil was 0·507° Fahrenheit; the gain with the writer's new oil was only 0·360° Fahrenheit; these figures being the averages of the whole number of experiments.

These results were satisfactory, precise, and conclusive to the writer's mind, and were arrived at in June, 1870.

Since then the new oil has been actively manufactured, and from 200 to 300 tons practically applied on two railways, who are at the present moment using the oil with satisfaction. It is satisfactory also that, at the end of twelve months' general use of the oil, the statement is made that there is less tendency to gum with this oil than when pure rape oil is used.

Considering that this is the most important step yet made in extending the use of mineral oil for heavy machinery, and that it offers great encouragement to perseverance, the writer hopes that machinists and engineers will give the matter the attention he thinks it deserves.

EXPERIMENTS MADE WITH NORTH-BRITISH ENGINE, No. 239.

1870.	Refined Rape.	Temp. of Journals on Arrival.	Temp. of Air on Arrival.	Gain of Heat.	1870.	New Oil.	Temp. of Journals on Arrival.	Temp. of Air on Arrival.	Gain of Heat.
June 22	Glasgow to Edinburgh..	92°	64°	28°	June 28	Glasgow to Edinburgh..	83°	60°	23°
	Edinburgh to Glasgow..	101°	68°	33°		Edinburgh to Glasgow..	93°	65°	28°
	Glasgow to Edinburgh..	93°	65°	28°		Glasgow to Edinburgh..	84°	65°	19°
,, 23	Glasgow to Edinburgh..	90°	60°	30°	,, 29	Glasgow to Edinburgh..	83°	62°	21°
,, 24	Glasgow to Edinburgh..	84°	56°	28°	,, 30	Glasgow to Edinburgh..	79°	60°	19°
	Edinburgh to Berwick..	87°	56°	31°		Edinburgh to Berwick..	79°	60°	19°
	Berwick to Edinburgh..	81°	56°	25°		Berwick to Edinburgh..	70°	52°	18
Average gain 29° = 507° Fah. per mile.					Average gain 21° = ·360° Fah. per mile.				
TENDER (BAD JOURNALS).									
June 22	Edinburgh to Glasgow..	109°	68°	41°	June 28	Edinburgh to Glasgow..	92°	65°	27°
,, 24	Edinburgh to Berwick..	110°	56°	54°	,, 30	Edinburgh to Berwick..	97°	60°	37°
	Average gain	..	..	47°		Average gain	..	..	32°

EXPERIMENTS WITH EXPRESS ENGINE BETWEEN CARLISLE AND EDINBURGH.

June 9	Edinburgh to Carlisle ..	..	..	62°	June 9	Carlisle to Edinburgh ..	..	..	54°
,, 13	Edinburgh to Carlisle ..	..	..	66°	,, 13	Carlisle to Edinburgh ..	..	..	56°
	Average gain	..	..	64°		Average gain	..	..	55°

The Chairman proposed a vote of thanks to Mr. Coleman for his paper. There was no doubt that if mineral oil could be so cheapened in cost, and be made as efficient as the other—for it was a mere question of cost—under those circumstances mineral oil would come very largely into use. Whether the experiments which Mr. Coleman had shown pointed to a very great gain in the use of mineral oil he was not prepared to say without further examination. The comparison seemed to be rather a rough one; and he confessed he was not quite clever enough in the comparison of mineral oils to say whether it indicated a very great gain. Perhaps some gentleman better acquainted with subjects of that nature would be able to offer some remarks upon it.

Mr. Coleman, in reply to some remarks, said the temperature of the air varied very much during these experiments; that was, one day was a hot summer day, and the other was a cold wintry day. When the air was lower in temperature there was less tendency to gain heat, because there was a loss of heat by radiation.

The Chairman asked, if there was a difference of temperature between Edinburgh and Glasgow, would the gain include this difference?

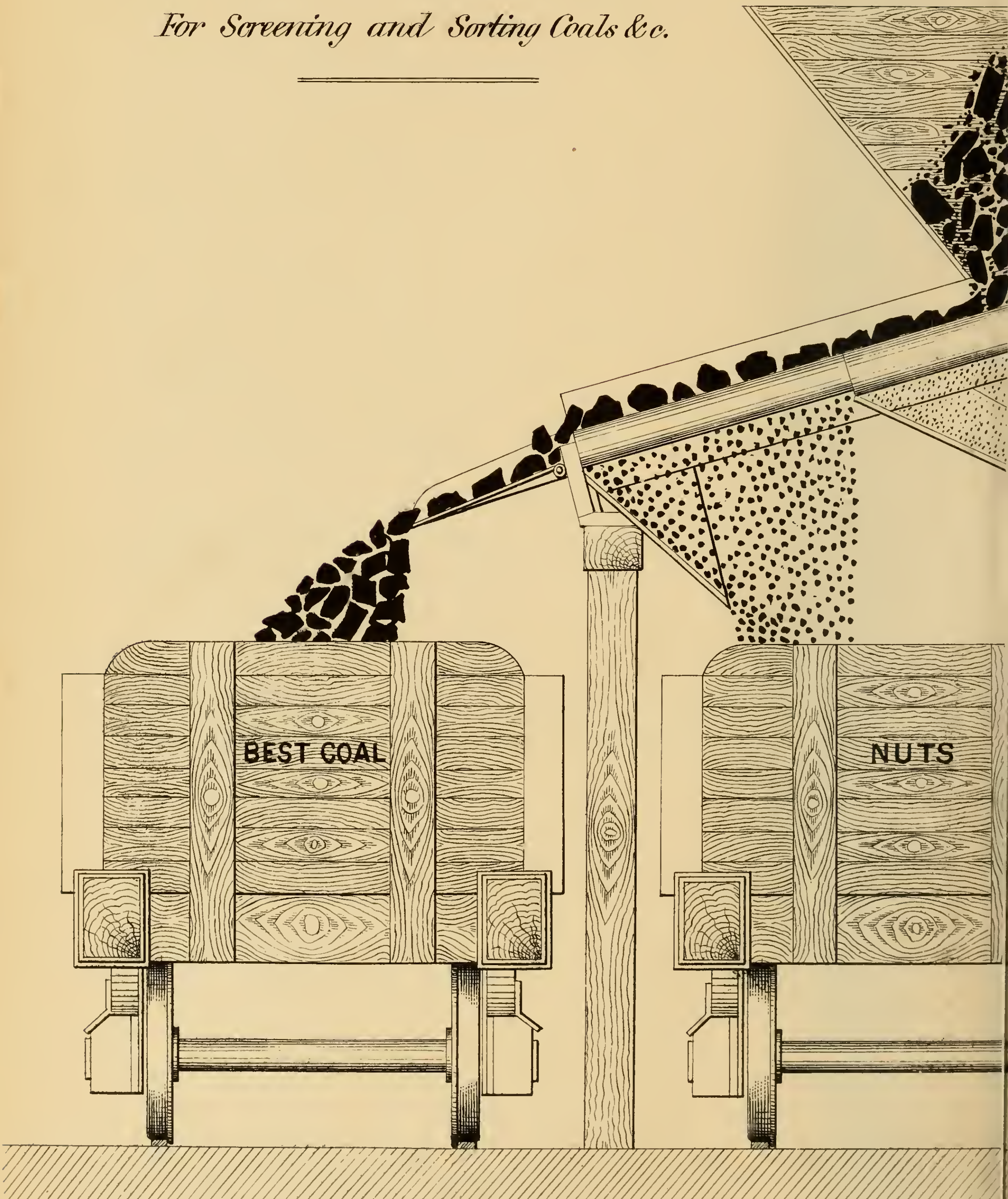
Mr. Coleman—No; the gain was simply the temperature of the atmosphere at the end of the journey, deducted from that of the axle taken also at the end of the journey.

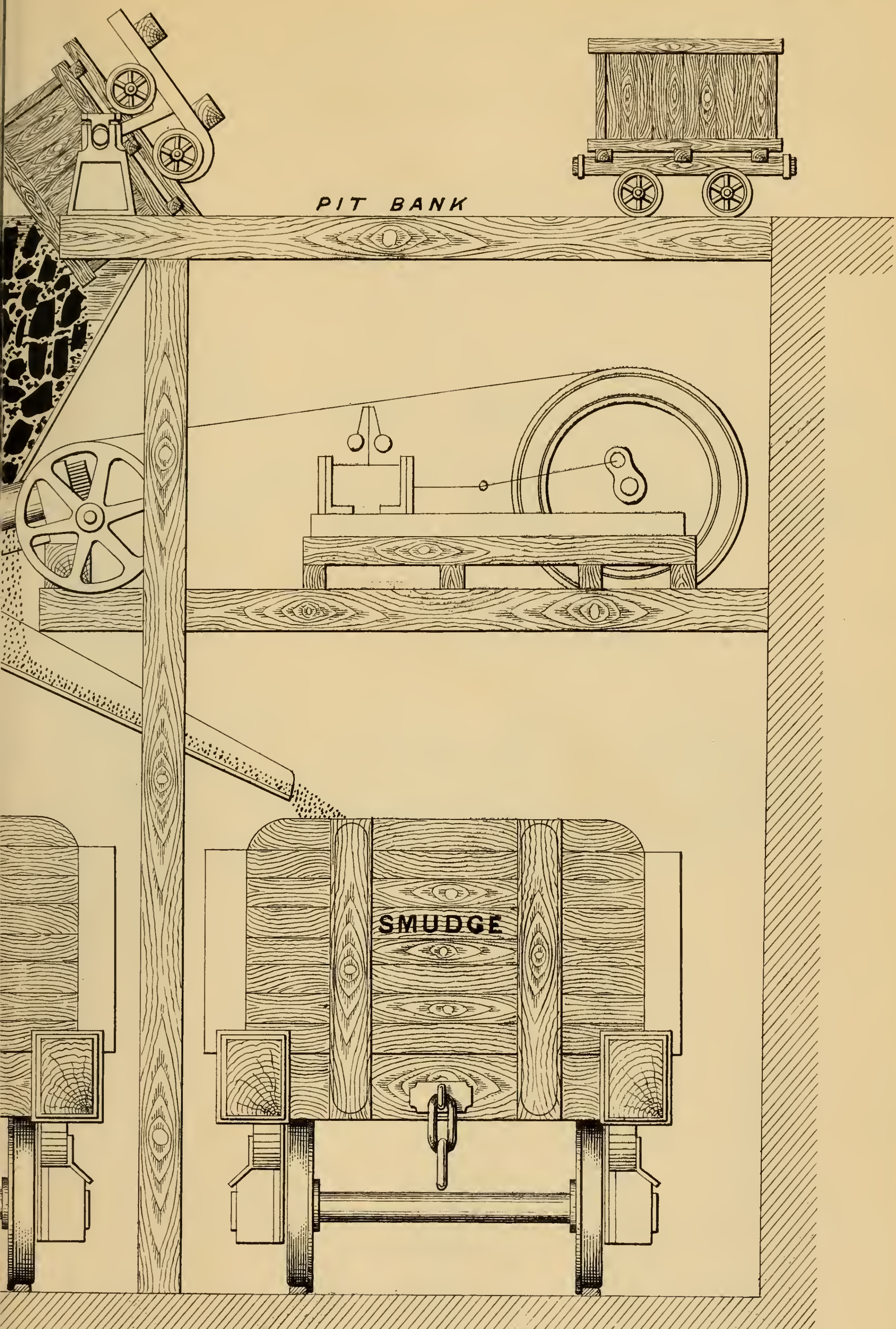
The Secretary then read a paper by Mr. R. Miller "On a New and Improved Method of Screening and Loading Coals."

HICKS' PATENT SCREEN,

WITH REVOLVING BARS,

For Screening and Sorting Coals &c.





And.w Reid, Newcastle.

Hicks' Patent Screen

With Revolving Bars

For Screening and Sorting Coals &c.

FIG. 1.

GEARING COVERED BY DEAD-PLATE

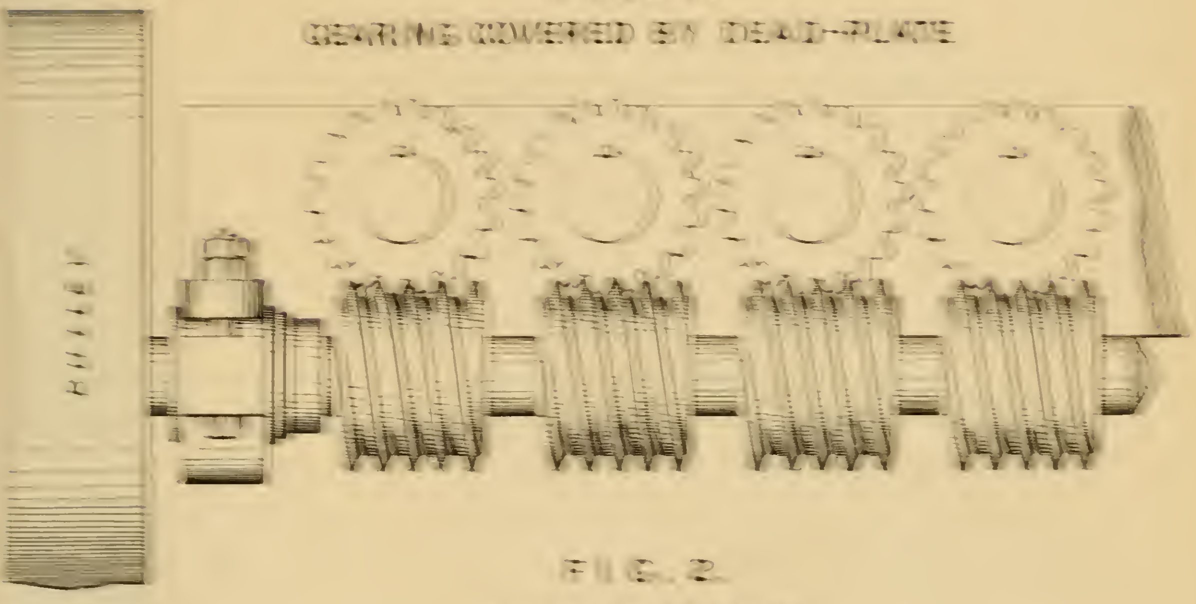
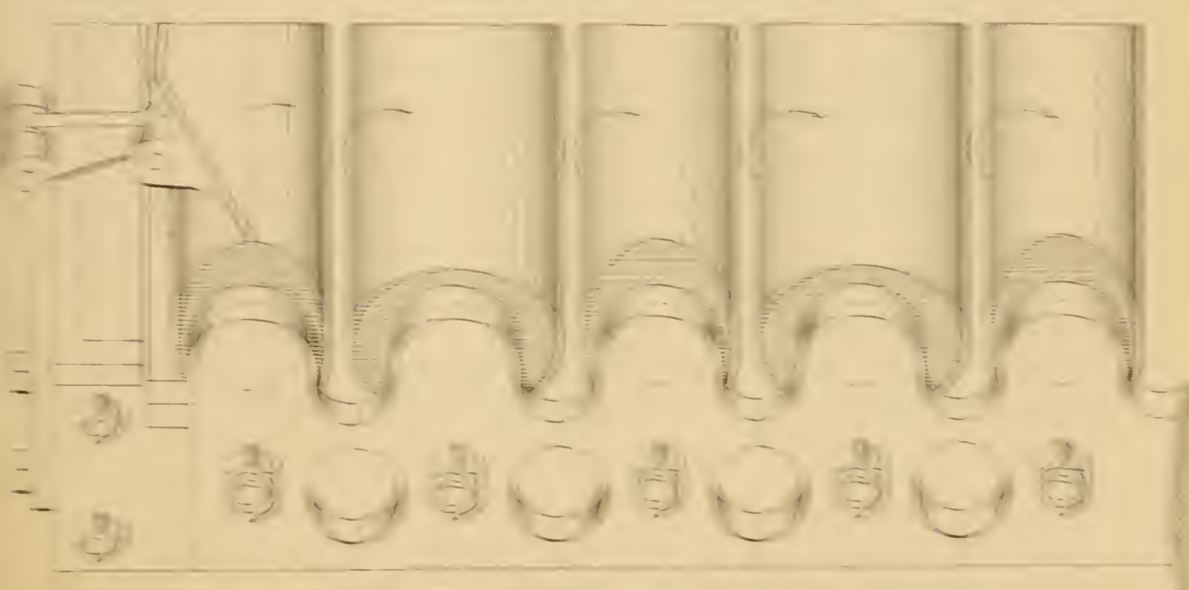


FIG. 2.

SECTION OF BARS

FIG. 3.

SCREEN FRAME – LOWER END



Scale 1½ inches = 1 foot

ON A NEW AND IMPROVED METHOD OF SCREENING AND LOADING COALS.

By ROBERT MILLER.

Whilst much attention has, of late years, been bestowed on the invention of improved machinery to expedite the various operations connected with the winning and bringing to bank of large quantities of coals, very little improvement has been noticed in the means employed for expeditiously screening and loading coals into wagons without waste and breakage, and at the same time taking out the small coal and dirt, in anything like an effectual manner.

The apparatus commonly used for screening is only of a rude description, for it is ineffective for removing all the small coal, while it causes great waste and loss from breakage of the larger coals.

It is proposed in this paper to describe a screen of an improved description which has been invented and patented by Mr. G. W. Hick, of Leeds, and has been successfully in operation at the Strafford Main Colliery, near Barnsley, for more than a year.

Plates XLVII. and XLVIII. show the screen which is composed of a number of bars set in frame, at a slight angle, so that each bar can be made to revolve slowly. The bars are oval in section, and revolve with the long diameter of each bar at right angles to the long diameter of the bar next to it.

The bars have a longitudinal space between each, which remains of the same width during all parts of the revolution. These spaces form the openings for the passage of the small coals, which, as the bars revolve together in the same direction, are not crushed nor broken, but pass freely down between the bars.

The relative position and configuration of these bars will be readily understood by reference to the section, figure 2, Plate XLVIII. The arrows show the direction of motion.

Figure 1, Plate XLVIII., shows the method employed for driving the bars at the upper end, whilst figure 3, Plate XLVIII., shows an end view of a portion of the screen frame at the lower end, explaining the manner of carrying the bars.

The method of working is as follows:—Attached over the upper end of the bars and covering the gearing is an inclined dead-plate, or hopper, Plate XLVII., on to which the coals are shot from the tub, and fixed at such an angle that the coals will slide on to the bars by their own weight, where the easy undulating motion produced by the slow revolution of the bars facilitates the free passage of the small coals down the spaces already mentioned as formed between the bars; whilst the larger coals are carried forward along the upper surface of the bars into the wagon, over which the lower ends of the bars project.

The comparatively slow, yet contiuous, speed at which the coals travel forward over the screen bars, enables an attendant to pick out from the moving mass all dirt, brasses, shale, etc., before the coals arrive in the wagon, and from the slight fall required (about 20 inches in 6 feet) the coals are not knocked about with rakes nor shovels, as is the case with ordinary screens, but are passed forward into the wagons with no more breakage than if dropped over the wagon-side by hand.

The screen at Strafford consists of eight oval bars about eight feet in length, and is driven by a strap from a small donkey engine, fixed beneath the dead-plate, and easy of access to the attendant on the screens.

The lower ends of the bars, figure 3, Plate XLVIII., revolve on fixed pins attached to the frame, the ends of the bars being bored out and fitted on to the pins. The lubrication of the pins is effected through holes in the bars, kept closed against the access of dust by countersunk-screws.

The single screen at the Strafford Colliery will, when required, screen and load an eight-ton wagon in fifteen minutes, well cleaned and picked, by two boys, one on each side of the screen.

With a moderate height of pit-heap, so that tubs can be emptied on to a dead-plate large enough, and with a descent so as to serve coals on to the revolving bars, it will be found that coals can be loaded fully twice as fast as by the ordinary method, where the tub of coals goes with a rush, either into the wagon or against a screen door, and is to be cleaned there before the next tub comes in a similar manner.

It is evident that by making the bars each of two separate diameters or sections for a certain part of their length, thus causing the spaces between the bars to be differential, the large diameter being at the upper end, the spaces at that end are narrowest and the smallest coal or dust passes down there. The next series of diameters being less, the spaces between the bars are of course wider, and the smithy coal or nuts pass down. Anything larger than these spaces will admit goes over the ends of the bars.

Hoppers or wagons are placed beneath for the reception of each class of coals.

The bars so made can either be made round, or the same two or more sets of diameters and spaces can also be applied to the oval bars quite as well.

It may seem strange on first thought, yet it is proved by experiment, that with so few bars and spaces in the width of the screens, the small is taken out more effectually than with many spaces in the same width of fixed bars; this result arises from the revolving bars producing a continuous easy motion of the coals sideways, thus continually feeding the few spaces there are with small coal, which is depositing freely from the mass of loose coal in motion; and owing to the revolution of the bars the spaces are not blocked with pieces sticking as in the ordinary way. This arrangement passes coals into wagons with the small all deposited through the spaces, without any great elevation of pit-head, and without any tumbling or raking by hand.

Besides the advantages here noted, this system seems to give greater facilities for picking and separating coals, or other minerals, which may be necessarily brought to the screen in a mixed state, for the bars in motion will spread the material over any length or width that may be required; it being only necessary to limit the width, so that a boy on each side of the screen can reach to pick out any substance from the mass of coal that is not required to pass into the wagon.

The screen which works now constantly at the Strafford Main Collieries has but one size for its spaces, so that the small goes through altogether; this is all that is required there, for a most effective system of separating the small into as many sorts as required had been in operation some time previous, and is still used with excellent results.

The writer still thinks that in screening and loading tender coal, an important saving may be made in the breakage compared with the old plan of coals going over the screens with a rush into the wagon, or being stopped on the screen and then shovelled into the wagon; and it may now be said, in conclusion, that when a load of coals comes to bank to be loaded into wagons into two or three sizes and sorts of coal, one representing say 100 in worth, and the others from 50 down to 10, it then becomes important to arrive at a system of handling which makes most of the best, and least of the worst; and if this method here described can effect anything towards these best results, then it will be wise to extend its adoption.

It will be noted that a small steam engine is required; the same engine, however, would drive a number of screens, and by an easy arrangement of clutch gear, idle screens may be put into motion or stopped as required.

The Chairman suggested that the discussion should be adjourned until the writer of the paper could be present.

The scrutineers announced the result of the election, when it was ascertained that Sir W. G. Armstrong, C.B., LL.D., F.R.S., had been elected President.

Mr. I. Lowthian Bell proposed, and Mr. Newall seconded, a vote of thanks to Mr. Boyd, the retiring President, for the attention he had at all times displayed to the interests of the Institute and for his great service in regard to the foundation of the College, which was carried by acclamation.

The meeting then separated.

APPENDIX No. I.

BAROMETER AND THERMOMETER READINGS FOR 1871.

By the Secretary.

These readings have been obtained from the observatories of Kew and Glasgow, and will give a very fair idea of the variations of temperature and atmospheric pressure in the intervening country, in which most of the mining operations in this country are carried on.

The Kew barometer is 34 feet, and the Glasgow barometer 180 feet above the sea level. The latter readings have been reduced to 32 feet above the sea level, by the addition of ·150 of an inch to each reading, and both readings are reduced to 32° Fahrenheit.

The fatal accidents have been obtained from the Inspectors' reports, and are printed across the lines, showing the various readings. The name of the colliery at which the explosion took place is given first, then the number of deaths, followed by the district in which it happened.

The non-fatal accidents are indicated in the same way; but where the name of the colliery has not been given a simple ——— has been substituted.

The writer here begs to thank those inspectors who were so kind as to send him particulars of the non-fatal accidents.

At the request of the Council the exact readings at both Kew and Glasgow have been published in figures.

The writer makes no attempt to offer any remarks, but hopes his efforts will be acceptable, and form data on which to build more effectual arrangements for the safety of life.

BAROMETER READINGS, &c.

JANUARY, 1871.

	KEW.							GLASGOW.					
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	30·156	30·118	30·013	29·952	28·9	17·1	1	29·782	29·678	29·599	29·635	34·5	30·0
2	29·898	29·914	29·894	29·921	28·0	25·7	2	29·677	29·757	29·747	29·745	35·1	30·0
3	29·935	30·015	30·053	30·119	33·2	26·0	3	29·767	29·871	29·923	29·937	35·8	31·5
4	30·105	30·145	30·153	30·200	32·2	23·0	4	29·907	29·903	29·869	29·811	38·9	32·0
5	30·142	29·942	29·816	29·964	40·1	25·2	5	29·555	29·453	29·635	29·785	42·0	43·5
6	30·088	30·173	30·045	29·923	43·6	32·0	6	29·833	29·607	29·477	29·369	46·6	33·5
7	29·787	29·740	29·637	29·587	44·6	33·6	7	29·313	29·281	29·249	29·244	46·2	32·3
8	29·554	29·549	29·553	29·579	39·3	32·8	8	29·281	29·405	29·422	29·376	36·8	30·0
9	29·470	29·346	29·505	29·666	35·6	31·0	9	29·261	29·385	29·514	29·619	35·3	29·5
10	29·749	29·740	29·504	29·387	36·0	27·1	10	29·611	29·527	29·438	29·576	36·0	27·0
11	29 560	29·762	29·851	29·942	34·0	30·6	11	29·692	29·825	29·976	30·062	36·5	27·8
12	30·033	30·141	30·172	30·232	34·6	24·0	12	30·106	30·148	30·102	30·019	36·2	24·5
13	30·239	30·233	30·162	30·114	36·7	19·7	13	29·923	29·872	29·812	29·725	45·2	34·5
14	30·013	29·968	29·882	29·799	43·3	36·4	14	29·546	29·426	29·328	29·266	46·4	41·5
15	29·663	29·520	29·395	29·340	39·8	36·2	15	29·104	28·974	28·937	28·891	43·5	35·5
16	28·998	28·892	28·883	28·914	44·0	36·6	16	28·453	28·302	28·401	28·386	42·3	33·4
17	28·904	28·956	28·956	28·977	39·0	35·4	17	28·432	28·517	28·591	28·717	40·6	36·6
18	29·012	29·092	29·098	29·170	43·7	34·1	18	28·817	28·960	29·045	29·161	39·2	29·1
19	29·239	29·371	29·448	29·502	38·7	28·8	19	29·181	29·229	29·299	29·429	39·5	26·6
20	29·490	29·547	29·580	29·661	38·3	32·8	20	29·517	29·607	29·660	29·673	35·8	30·0
21	29·712	29·744	29·666	29·603	38·2	35·7	21	29·637	29·598	29·536	29·528	35·6	29·5
22	29.528	29·547	29·542	29·584	43·8	31·0	22	29·552	29·636	29·702	29·782	36·3	30·2
23	29·655	29·739	29·821	29 941	38·6	35·6	23	29·859	29·948	30·021	30·149	33·2	27·0
24	30·001	30·058	30·064	30·079	36·9	32·0	24	30·157	30·281	30·290	30·312	32·9	23·9
25	30·063	30·035	29·978	29·988	32·7	29·1	25	30·277	30·230	30·160	30·112	29·0	22·0
26	29·990	30·019	30·032	30·012	33·1	26·4	26	30·052	30·056	30·074	30·138	31·1	21·9
27	30·166	30·228	30·215	30·235	33·6	25·6	27	30·158	30·214	30·226	30·256	33·4	25·6
28	30·202	30·195	30·134	30·142	33·0	30·0	28	30·228	30·246	30·188	30·182	34·0	21·8
29	30·142	30·182	30·168	30·174	35·6	32·3	29	......	30·192	......	......	34·0	29·0
30	30·119	30·109	30·116	30·187	33·6	29·9	30	......	30·235	......	30·178	34·6	28·0
31	30·210	30·238	30·174	30·141	33·4	30·0	31	......	30·177	......	30·150	35·0	30·2

FEBRUARY, 1871.

1	30·057	30·025	29·988	29·987	36·4	30·0	1	30·130	30·127	30·061	30·063	36·1	25·0
2	29·983	30·011	29·968	29·919	37·6	33·9	2	30·029	30·013	29·945	29·891	34·2	30·3
3	29·804	29·724	29·691	29·726	43·3	34·6	3	29·802	29·694	29·621	29·605	34·5	28·8
4	29·708	29·708	29·669	29·675	48·0	41·4	4	29·609	29·639	29·604	29·572	39·4	32·6
5	29·675	29·723	29·673	29·613	49·5	43·2	5	29·489	29·364	29·147	29·191	46·3	36·1
6	29·685	29·883	30·026	30·143	52·5	43·0	6	29·434	29·722	29·909	29·977	51·0	36 2
7	30·164	30·169	30·066	30·021	49·2	40·8	7	29·959	29·886	29·762	29·752	48·4	36·6
8	29·989	29·938	29·853	29·797	51·7	43·1	8	29·696	29·606	29·555	29·562	48·2	38·1
9	29·829	29·943	29·991	30·011	48·0	36·4	9	29·641	29·795	29·823	29·747	46·9	36·5
10	29·829	29·347	29·219	29·644	44·8	32·6	10	29·445	29·373	29·689	29·899	42·2	35·4
11	29·973	30·123	30·123	30·077	32·4	25·6	11	29·950	29·947	29·864	29·662	34·8	31 6
12	29·904	29·787	29·656	29·636	41·5	27·9	12	29·418	29·283	29·291	29·443	40·8	30·5
13	29·701	29·891	30·019	30·116	49·2	34·8	13	29·629	29·786	29·821	29·811	43·4	37·0
14	30·129	30·164	30·124	30·136	46·5	33·7	14	29·827	29·837	29·805	29·761	49·5	41·6
15	30·100	30·146	30·144	30·162	48·6	38·6	15	29·799	29·903	29·901	29·930	47·0	42·6
16	30·151	30·182	30·157	30·168	46·6	41·0	16	29·914	29·962	29·953	29·921	46·0	45·1
17	30·138	30·163	30·166	30·216	49·4	41·9	17	29·833	29·803	29·845	29·883	50·6	43·2
18	30·209	30·248	30·211	30·203	53·6	40·6	18	29·845	29·837	29·846	29·810	54·7	44·4
19	30·147	30·089	29·960	29·831	53·5	44·8	19	29·742	29·600	29·502	29·316	52·3	47·0
20	29·706	29·754	29·759	29·823	49·7	40·5	20	29·138	29·394	29·521	29·545	49·0	40·0
21	29·814	29·962	30·150	30·336	46·4	39·1	21	29·815	30·121	30·178	30·208	47·0	40 0
22	30·397	30·430	30·362	30·362	48·4	33 0	22	30·162	30·096	29·990	30·020	51·1	49·0
23	30·312	30·368	30·336	30·392	52·7	38·6	23	30·066	29·996	30·073	30·141	52·0	41·8
24	30·406	30·405	30·324	30·332	47·4	37·7	24	30·041	30·011	29·960	29·974	49·8	46·2
25	30·323	30·338	30·287	30·254	46·3	40·3	25	29·950	30 026	30·057	30·083	51·7	44·8
26	30·149	30·048	29·924	29·868	50·6	38·6	26	30·015	29·902	29·722	29·562	46·2	41·5
27	29·798	29·744	29·789	29·781	56·0	48·7	27	29·384	29·418	29·480	29·484	44·3	40·2
28	29·679	29·854	30·064	30·298	52·6	40·1	28	29·608	29·949	30·138	30·292	46·0	36·9

BAROMETER READINGS, &c.

MARCH, 1871.

KEW.							GLASGOW.						
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	30·414	30·480	30·410	30·419	45·1	34·5	1	30·334	30·343	30·280	30·262	42·9	35·0
2	30·390	30·392	30·311	30·314	56·0	32·0	2	30·208	30·164	30·088	30·091	52·0	38·5
3	30·283	30·279	30·157	30·147	62·2	30·8	3	30·087	30·094	30·009	29·936	60·6	45·1
4	30·054	30·026	29·937	29·971	60·6	33·3	4	29·853	29·795	29·687	29·623	54·7	44·5
5	29·987	30·025	29·932	29·823	54·1	44·4	5	......	29·535	......	......	51·3	46·0
6	29·705	29·629	29·549	29·585	54·9	47·8	6	......	29·288	......	29·251	55·0	45·0
7	29·595	29·748	29·854	29·817	51·3	42·8	7	......	29·564	......	29·155	48·5	37·8
8	29·659	29·907	30·029	30·168	50·6	38·0	8	......	29·496	......	29·838	56·0	35.2
9	30·297	30·263	29·871	29·991	49·4	35·0	9	......	29·682	......	29·701	51·6	35·1
10	30·065	30·099	30·111	30·161	52·0	38·4	10	......	29·845	......	29·822	46·0	37·0
11	30·035	30·026	29·974	29·990	55·0	42·2	11	......	29·538	......	29·490	49·5	41·4
12	29·904	29·802	29·661	29·631	55·0	47·6	12	29·353	29·177	29·089	29·089	48·9	43·5
13	29·625	29·663	29·716	29·837	51·3	40·9	13	29·131	29·201	29·321	29 533	45·2	37·0
14	29·828	29·861	29·790	29·842	49·0	36·9	14	29·587	29·722	29·739	29·751	35 3	24·0
15	29·838	29·881	29·852	29·744	40·6	32·4	15	29·783	29·781	29·589	29·379	40·0	24·7
16	29·296	29·313	29·789	30·045	41·4	33·5	16	29·509	29·816	29·950	30·088	42·0	30·2
17	30·142	30·276	30·255	30·260	45·3	31·8	17	30·088	30·068	30·094	30·162	49 3	29·1
18	30·260	30·302	30·248	30·265	55·2	39·8	18	30·188	30·226	30·164	30·134	51·5	35·3
19	30·222	30·218	30·110	30·130	56·7	42·0	19	30·058	30·036	29·996	29·964	51·9	44·0
20	30·075	30·069	29·995	30·031	46·3	35·6	20	29·877	29·826	29·763	29·725	51·5	45·5
21	30·017	30·055	30·011	30·070	54·0	35·7	21	29·668	29·703	29·697	29·761	53·4	43·3
22	30·086	30·111	30·032	30·038	53·4	32·0	22	29·848	29·963	29·996	30·036	52·0	44·5
23	29·976	29·984	29·918	29·921	65·3	37·5	23	30·028	30·016	29·883	29·911	59·6	37·6
24	29·833	29·831	29·776	29·833	66·6	36·8	24	29·873	29·829	29·737	29·765	53·2	39·5
25	29·809	29·865	29·840	29·890	63·3	40·9	25	29·761	29·793	29·784	29·907	61·5	32·5
26	29·899	29·935	29·914	29·974	64·4	44·6	26	29·940	29·985	29·948	30·016	54·3	39·5
27	29·966	30·072	30·112	30·251	52·0	38·6	27	30·129	30·245	30·285	30·375	47·2	36·7
28	30·313	30·384	30·396	30·435	42·4	32·6	28	30·459	30·522	30·520	30·547	42·6	32·5
29	30·407	30·403	30·285	30·280	47·0	32·2	29	30·497	30·444	30·331	30·341	52·2	27·0
30	30·272	30·296	30·238	30·218	48·5	40·6	30	30·297	30·296	30·198	30·166	51·3	32·2
31	30·137	30·074	29·964	29·922	52·3	41·0	31	30·016	29·940	29·897	29·941	55·4	41·1

APRIL, 1871.

1	29·915	29·943	29·929	29·960	49·1	38·9	1	29·927	29·937	29·909	29·891	47·4	35·6
2	29·928	29 929	29·828	29·786	52 2	39·7	2	29 825	29·748	29·643	29·632	51·3	35·7
3	29·694	29·739	29·806	29·938	53·2	41·4	3	29·667	29·805	29·876	29·952	45·8	34·5
4	30·028	30·103	30·071	30·079	51·5	38·4	4	29 956	29 934	29·923	29·930	53·0	35·0
5	30·029	30·024	29·998	30·035	53 0	37·7	5	29·891	29 900	29·971	30·051	48·6	36·8
6	30·085	30 167	30·157	30·198	49 6	34·8	6	30·079	30·129	30·096	30·134	50·7	34·8
7	30·173	30·180	30·120	30·128	50·2	31·4	7	30·128	30·140	30·099	30·129	54·0	34·5
8	30·078	30·067	30·000	30·013	54·0	31·5	8	30·107	30·093	29·998	30·013	55·4	30·4
9	29·963	29·959	29·924	29·944	51·2	35·6	9	29·973	29·976	29·975	30·015	47·6	35·4
10	29·948	29·978	29·961	30·027	51·9	34·5	10	30·013	30·017	29·955	29·982	51·3	30·5
11	30·040	30·048	29·975	29·872	52 6	30·4	11	29·979	29·931	29·755	29·630	53·5	31·2
12	29·820	29·842	29·902	29·979	62 6	50 0	12	29·557	29·611	29·626	29·720	56·9	41·5
13	29·994	30·036	30 001	30·010	62·0	47·8	13	29·778	29 854	29·904	29·946	58·5	42·6
14	29·956	29·902	29·724	29·590	61·0	41·0	14	29·894	29 814	29·6[illegible]0	29·504	45·4	40·4
15	29·354	29·306	29·363	29·464	58 0	47 8	15	29·334	29·234	29·157	29·177	51·2	44·0
16	29·336	29·380	29·442	29·499	55·4	49 2	16	29·165	29·205	29·241	29·303	58·6	41·5
17	29·327	29·426	29·525	29·644	59·8	46·6	17	29·345	29·451	29 559	29·[illegible]55	49·0	38·4
18	29·657	29·631	29·459	29·389	54·6	48·5	18	29·669	29·655	29·521	29·351	42·6	34·8
19	29·245	29·165	29·159	29·263	57·5	45·6	19	29 167	29·067	29·028	29·068	42·0	35·0
20	29·277	29·355	29·386	29·322	53 5	43·0	20	29·114	29·226	29·277	29·345	46·1	34·8
21	29·376	29·562	29·681	29·777	56·5	47·4	21	29 425	29·541	29·592	29·662	51·0	35·8
22	29·788	29·751	29·664	29 692	60 0	49·5	22	29·63[illegible]	29·522	29·454	29·359	43·8	38·4
23	29·617	29·632	29·704	29·820	58·3	46 4	23	29 376	29·612	29·773	29·869	45·8	38·1
24	29·854	29·929	29·949	29·986	52 6	42·0	24	29·897	29·953	30·965	30·005	47·0	37·4
25	29·998	30·057	30·020	30·032	58·7	44·0	25	30 007	30 010	29·940	29·904	50·2	36·0
26	29·986	29·971	29·893	29·844	60·1	43 4	26	29·802	29·750	29·677	29·684	48·8	40·2
27	29·754	29·749	29·763	29·813	61 0	46·4	27	29 626	29 618	29·585	29·602	53·6	39·5
28	29·817	29·847	29·788	29·693	58·4	46·1	28	29·577	29 565	29·541	29·547	50·8	43·8
29	29·561	29·493	29·493	29·602	60·8	48·6	29	29·517	29·529	29·531	29·623	58·4	34·5
30	29·703	29·814	29·835	29·931	57·6	43·7	30	29 665	29·719	29·745	29·867	55·2	39·0

BAROMETER READINGS, &c.

MAY, 1871.

	KEW.							GLASGOW.					
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	30·001	30·071	30·088	30·118	56·6	40·6	1	29·963	30·015	30·001	29·997	53·0	35·0
2	30·102	30·116	30·067	30·053	57·0	37·0	2	29·963	29·957	29·913	29·872	56·7	38·5
3	29·973	29·915	29·800	29·845	62·6	36·9	3	29·699	29·556	29·547	29·379	49·5	38·0
4	29·878	29·931	29·950	30·033	53·1	40·1	4	29·501	29·681	29·819	29·939	52·6	39·9
5	30·079	30·153	30·119	30·162	62·0	37·4	5	29·969	29·983	29·948	30·042	48·7	39·1
6	30·180	30·217	30·206	30·290	66·6	48·5	6	30·112	30·190	30·225	30·281	64·8	41·3
7	30·310	30·355	30·333	30·332	57·5	43·1	7	30·311	30·331	30·290	30·308	73·4	43·0
8	30·296	30·227	30·087	30·138	70·7	39·2	8	30·257	30·217	30·168	30·238	68·8	44·1
9	30·134	30·126	30·122	30·192	51·4	42·3	9	30·258	30·274	30·234	30·275	58·5	37·0
10	30·195	30·206	30·180	30·197	51·0	38·9	10	30·284	30·265	30·296	30·184	57·6	34·5
11	30·154	30·138	30·024	29·994	53·1	39·1	11	30·099	30·050	30·028	30·042	54·3	39·6
12	29·987	30·018	29·974	30·001	57·0	34·0	12	30·052	30·054	30·008	30·051	56·5	38·2
13	29·992	29·996	29·952	29·930	49·0	42·6	13	30·058	30·034	29·942	29·913	59·1	38·8
14	29·872	29·850	29·794	29·824	54·2	40·9	14	29·866	29·838	29·806	29·844	53·3	42·0
15	29·828	29·860	29·831	29·883	57·0	38·4	15	29·868	29·882	29·832	29·836	53·0	39·4
16	29·862	29·851	29·829	29·855	60·0	36·0	16	29·816	29·832	29·851	29·982	49·6	37·6
17	29·911	30·008	29·952	29·936	54·6	40·0	17	30·017	29·946	29·696	29·671	48·7	27·6
18	29·862	29·889	29·969	30·051	58·6	41·5	18	29·716	29·838	29·874	29·954	55·6	42·7
19	......	30·160	30·168	30·225	65·4	44·4	19	29·972	30·028	30·077	30·155	57·5	42·8
20	30·240	30·269	30·221	30·263	65·4	46·4	20	30·114	30·110	30·140	30·206	61·0	47·4
21	30·262	30·316	30·278	30·304	66·0	46·8	21	30·217	30·230	30·201	30·199	64·3	45·5
22	30·274	30·220	30·127	30·096	61·6	41·9	22	30·173	30·145	30·076	30·044	71·2	45·2
23	30·035	29·999	29·949	29·935	66·9	48·0	23	30·022	29·972	29·871	29·879	73·0	49·8
24	29·893	29·886	29·826	29·803	77·7	43·8	24	29·889	......	29·764	29·734	75·6	50·3
25	29·796	29·776	29·795	29·839	75·0	57·6	25	29·672	29·719	29·717	29·757	64·4	51·7
26	29·889	29·941	29·960	30·006	60·9	48·5	26	29·763	29·797	29·828	29·881	57·8	45·8
27	29·772	29·985	29·961	30·006	60·6	42·0	27	29·895	29·965	30·031	30·200	65·6	43·5
28	30·030	30·091	30·076	30·174	67·3	49·1	28	30·273	30·327	30·309	30·329	67·0	50·1
29	30·198	30·241	30·202	30·238	64·0	46·4	29	30·305	30·263	30·212	30·207	76·0	43·3
30	30·214	30·191	30·091	30·080	74·6	43·0	30	30·170	30·144	30·109	30·146	70·0	49·2
31	30·118	30·131	30·108	30·112	65·5	48·1	31	30·125	30·108	30·054	30·036	70·4	55·6

JUNE, 1871.

1	30·068	30·012	30·040	30·122	68·0	44·1	1	30·043	30·092	30·084	30·164	65·9	47·5
2	30·130	30·133	30·137	30·186	54·6	40·9	2	30·206	30·231	30·225	30·295	59·8	40·2
3	30·176	30·176	30·103	30·095	54·0	40·8	3	30·279	30·253	30·152	30·106	55·8	40·0
4	30·015	29·979	29·995	30·100	54·9	39·2	4	30·038	30·070	......	......	57·0	48·1
5	30·126	30·154	30·116	30·157	60·4	41·4	5	......	30·193	30·182	30·189	66·5	46·2
6	30·108	30·061	29·979	30·010	60·6	41·4	6	30·125	30·104	30·063	30·109	67·9	52·0
7	29·950	29·935	29·891	29·911	58·1	45·1	7	30·091	30·069	30·055	30·065	65·4	51·2
8	29·899	29·913	29·879	29·897	55·3	46·4	8	30·031	30·000	29·945	30·001	66·3	45·2
9	29·887	29·918	29·941	29·960	60·2	46·0	9	30·007	30·025	30·000	30·016	61·5	43·6
10	29·962	29·973	29·945	29·954	63·6	49·2	10	30·010	29·972	29·925	29·939	68·7	43·0
11	29·957	29·961	29·930	29·980	64·1	49·0	11	29·939	29·945	29·925	29·949	61·7	50·8
12	29·991	30·034	29·993	30·017	66·1	47·6	12	29·987	30·027	29·992	30·026	64·4	47·2
13	29·975	29·951	29·916	29·909	65·6	48·5	13	29·986	29·876	29·786	29·778	65·5	43·2
14	29·864	29·911	29·930	29·911	71·1	58·1	14	29·764	29·784	29·784	29·860	69·6	52·5
15	29·833	29·842	29·768	29·763	72·3	58·0	15	29·870	29·866	29·832	29·828	61·4	50·5
16	29·754	29·802	29·758	29·765	73·1	57·4	16	29·712	29·696	29·688	29·716	68·3	49·4
17	29·665	29·581	29·504	29·491	67·0	56·3	17	29·668	29·606	29·476	29·414	69·8	50·0
18	29·522	29·594	29·558	29·561	66·0	54·8	18	29·372	29·406	29·392	29·428	69·0	51·1
19	29·547	29·560	29·556	29·570	66·1	53·7	19	29·440	29·448	29·459	29·517	66·7	45·6
20	29·534	29·590	29·649	29·710	67·2	55·2	20	29·544	29·587	29·637	......	64·5	50·0
21	29·735	29·818	29·859	29·899	65·2	54·3	21	29·777	29·837	29·835	29·883	62·6	49·1
22	29·890	29·923	29·895	29·845	62·1	51·6	22	29·905	29·913	29·914	29·968	56·6	45·0
23	29·781	29·822	29·884	29·977	61·4	49·6	23	29·993	30·043	30·053	30·129	58·2	43·0
24	30·000	30·059	30·074	30·144	60·4	47·6	24	30·157	30·181	30·158	30·182	60·7	43·7
25	30·139	30·146	30·147	30·221	59·3	42·3	25	30·179	30·186	30·166	30·242	64·2	43·6
26	30·238	30·249	30·223	30·201	61·4	43·7	26	30·269	30·258	30·170	30·125	64·2	43·8
27	30·131	30·061	30·010	29·971	64·6	41·3	27	30·033	29·986	29·874	29·740	64·5	45·1
28	29·774	29·666	29·732	29·829	68·0	52·0	28	29·516	29·464	29·570	29·660	57·9	51·0
29	29·864	29·842	29·797	29·776	67·4	52·6	29	29·693	29·670	29·629	29·538	60·9	51·4
30	29·716	29·730	29·775	29·870	70·1	53·0	30	29·458	29·534	29·560	29·634	65·2	52·5

BAROMETER READINGS, &c.

JULY, 1871.

KEW.							GLASGOW.						
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·907	29·925	29·897	29·911	70·3	47·5	1	29·666	29·703	29·710	29·732	65·8	53·1
2	29·844	29·744	29·585	29·547	65·4	50·5	2	29·703	29·686	29·620	29·584	68·0	52·5
3	29·451	29·547	29·624	29·728	66·5	55·2	3	29·537	29·508	29·476	29·520	65·2	52·0
4	29·748	29·703	29·708	29·838	66·3	53·8	4	29·530	29·546	29·551	29·571	63·7	51·5
5	29·874	29·922	29·955	30·101	69·3	51·5	5	29·601	29·661	29·733	29·865	65·2	48·0
6	30·171	30·207	30·179	30·189	67·7	51·1	6	29·897	29·815	29·783	29·837	68·0	50·5
7	30·142	30·072	29·945	29·868	74·9	57·0	7	......	29·764	29·692	29·644	63·0	54·0
8	29·813	29·874	29·875	29·927	69·6	58·0	8	29·590	29·588	29·546	29·619	64·0	50·4
9	29·957	29·974	29·961	29·995	69·7	55·5	9	29·625	29·679	29·681	29·729	65·5	50·1
10	29·978	29·954	29·838	29·751	72·3	50·1	10	29·745	29·793	29·786	29·794	68·8	51·5
11	29·572	29·594	29·729	29·860	62·2	51·9	11	29·774	29·796	29·785	29·811	68·5	50·2
12	29·897	29·903	29·901	29·857	67·7	51·3	12	29·786	29·747	29·680	29·628	67·8	47·5
13	29·813	29·866	29·886	29·926	71·0	54·5	13	29·592	29·618	29·580	29·536	62·2	54·1
14	29·936	29·973	29·980	29·985	71·3	61·6	14	29·638	29·704	29·672	29·706	72·5	55·4
15	29·975	30·030	30·024	30·040	76·1	61·6	15	29·754	29·777	29·629	29·687	64·2	56·2
16	30·071	30·143	30·132	30·146	79·9	61·4	16	29·880	29·996	30·016	29·966	67·0	53·2
17	30·112	30·099	30·025	30·032	79·6	59·9	17	29·818	29·860	29·889	29·940	64·5	54·5
18	30·050	30·053	29·998	29·973	76·5	60·2	18	29·930	29·962	29·938	29·882	63·8	52·5
19	29·874	29·790	29·667	29·693	78·3	55·9	19	29·784	29·662	29·637	29·689	61·5	48·3
20	29·763	29·906	29·973	30·008	69·5	57·8	20	29·759	29·861	29·886	29·874	67·7	47·8
21	29·971	29·957	29·839	29·807	71·6	58·2	21	29·772	29·680	29·569	29·531	63·3	52·6
22	29·691	29·648	29·615	29·682	71·3	57·0	22	29·457	29·433	29·384	29·392	66·4	51·5
23	29·651	29·650	29·643	29·671	68·9	54·5	23	29·382	29·446	29·486	29·512	65·0	51·8
24	29·654	29·667	29·596	29·501	67·9	53·9	24	29·496	29·460	29·370	29·270	61·5	51·4
25	29·328	29·381	29·411	29·448	66·1	54·2	25	29·202	29·196	29·179	29·163	61·3	49·4
26	29·407	29·406	29·423	29·417	66·1	53·7	26	29·113	29·163	29·251	29·329	61·5	44·5
27	29·505	29·700	29·801	29·852	72·8	52·0	27	29·431	29·467	29·675	29·725	66·2	47·8
28	29·757	29·716	29·874	29·979	70·3	55·3	28	29·686	29·687	29·637	29·721	62·5	46·5
29	29·955	29·878	29·732	29·704	70·3	52·2	29	29·731	29·701	29·606	29·512	60·5	45·0
30	29·678	29·617	29·706	29·793	66·1	52·0	30	29·494	29·526	29·585	29·711	68·5	46·5
31	29·873	29·981	30·012	30·068	72·5	47·5	31	29·789	29·878	29·917	29·951	66·5	49·5

AUGUST, 1871.

1	30·077	30·084	30·026	30·018	70·7	49·0	1	29·928	29·903	29·871	29·845	62·3	47·2
2	29·982	29·960	29·898	29·885	76·0	47·6	2	29·829	29·822	29·765	29·665	63·5	55·6
3	29·807	29·738	29·664	29·669	75·7	49·5	3	29·525	29·457	29·403	29·417	62·0	53·3
4	29·649	29·707	29·789	29·926	65·5	51·4	4	29·344	29·513	29·644	29·797	62·0	50·5
5	30·022	30·107	30·126	30·186	69·4	48·1	5	29·858	29·856	29·886	29·968	65·3	48·6
6	30·200	30·193	30·117	30·131	77·4	59·9	6	30·008	30·090	30·124	30·150	67·3	57·2
7	30·208	30·193	30·117	30·131	77·2	54·0	7	30·128	30·112	30·047	30·042	76·3	51·5
8	30·109	30·101	30·066	30·109	77·0	54·9	8	30·047	30·059	30·020	30·046	75·7	51·3
9	30·104	30·130	30·092	30·131	79·0	53·6	9	30·056	30·076	30·054	30·066	74·7	53·6
10	30·137	30·145	30·100	30·128	80·4	53·9	10	30·054	30·031	30·003	29·983	75·1	53·0
11	30·108	30·116	30·061	30·101	83·4	54·6	11	29·995	30·025	30·025	30·032	71·9	59·4
12	30·079	30·070	30·017	30·029	85·4	56·4	12	30·024	30·036	30·019	30·037	72·5	59·1
13	29·979	29·955	29·895	29·932	84·4	62·6	13	30·033	30·061	30·042	30·058	69·8	52·7
14	29·932	29·929	29·860	29·942	80·3	61·5	14	30·040	30·040	29·979	29·995	71·0	45·0
15	29·911	29·931	29·893	29·946	76·7	57·9	15	29·961	29·967	29·933	29·945	64·3	43·2
16	29·942	29·953	29·889	29·941	78·2	54·5	16	29·917	29·931	29·898	29·899	64·7	51·0
17	29·870	29·841	29·729	29·675	79·0	56·0	17	29·827	29·786	29·664	29·584	69·3	48·1
18	29·465	29·427	29·389	29·503	69·1	59·0	18	29·447	29·388	29·362	29·446	65·6	56·4
19	29·664	29·841	29·951	30·070	69·4	56·3	19	29·552	29·684	29·788	29·906	62·6	48·7
20	30·089	30·071	29·996	29·978	71·0	49·7	20	29·912	29·846	29·606	29·484	57·4	42·6
21	29·937	30·001	30·064	30·135	73·0	59·1	21	29·636	29·874	30·023	30·103	61·8	48·5
22	30·118	30·083	29·992	29·969	73·5	53·4	22	30·075	29·999	29·867	29·757	61·5	44·0
23	29·935	29·911	29·877	29·883	68·0	58·4	23	29·655	29·602	.....	29·645	64·3	53.5
24	29·890	29·823	29·689	29·730	67·0	57·0	24	29·595	29·431	28·971	29·251	64·2	53·3
25	29·804	29·886	29·901	29·992	69·6	55·5	25	29·415	29·537	29·578	29·641	61·5	49·0
26	30·035	30·120	30·152	30·270	67·3	51·7	26	29·598	29·654	29·937	30·123	61·6	48·4
27	30·358	30·443	30·446	30·456	67·8	48·0	27	30·121	30·271	30·322	30·364	60·6	48·8
28	30·440	30·444	30·349	30·331	71·1	46·4	28	30·366	30·372	30·311	30·263	68·5	51·5
29	30·233	30·196	30·083	30·079	74·6	51·2	29	30·190	30·021	30·045	30·059	72·2	49·5
30	30·014	29·984	29·942	29·962	80·5	55·8	30	29·985	29·939	29·845	29·859	75·2	51·4
31	29·975	30·021	29·994	30·034	73·7	57·1	31	29·853	29·871	29·831	29·853	71·8	53·8

BAROMETER READINGS, &c.

SEPTEMBER, 1871.

KEW.							GLASGOW.						
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	30·044	30·071	30·030	30·050	78·6	54·4	1	29·853	29·880	29·941	30·022	63·4	52·2
2	30·032	30·021	29·962	29·946	77·0	57·6	2	29·998	29·964	29·884	29·784	65·0	46·5
3	29·886	29·857	29·831	29·844	69·2	58·0	3	29·672	29·614	29·557	29·524	66·0	55·3
4	29·786	29·792	29·799	29·842	67·1	56·8	4	29·521	29·584	29·617	29·693	65·3	52·3
5	29·960	30·081	30·084	30·135	71·2	50·5	5	29·764	29·903	29·927	29·945	64·8	50·5
6	30·104	30·043	29·885	29·833	71·4	45·5	6	29·901	29·893	29·892	29·885	61·4	53·0
7	29·875	29·985	29·976	29·999	69·0	52·0	7	29·806	29·797	29·813	29·831	62·3	50·8
8	29·940	29·887	29·772	29·713	69·0	50·5	8	29·800	29·815	29·744	29·771	63·2	53·4
9	29·618	29·650	29·757	29·909	65·0	51·5	9	29·746	29·692	29·625	29·801	58·7	50·8
10	29·887	29·882	29·804	29·848	71·7	53·8	10	29·903	29·929	29·885	29·997	67·0	48·3
11	29·845	29·923	29·918	30·021	74·7	59·1	11	30·001	30·093	30·112	30·205	65·7	52·5
12	30·064	30·122	30·099	30·182	73·0	58·4	12	30·240	30·292	30·288	30·340	62·6	54·2
13	30·182	30·220	30·199	30·246	66·0	57·4	13	30·346	30·372	30·359	30·374	59·3	53·2
14	30·242	30·269	30·203	30·242	63·6	57·4	14	30·368	30·380	30·303	30·323	62·5	49·5
15	30·201	30·207	30·158	30·186	68·7	55·2	15	......	30·289	......	30·249	65·3	42·4
16	30·173	30·211	30·206	30·236	68·5	55·2	16	......	30·311	30·310	30·360	62·0	43·7
17	30·198	30·201	30·150	30·162	63·6	52·2	17	30·335	30·340	30·279	30·277	57·0	50·1
18	30·127	30·132	30·089	30·100	60·0	51·4	18	30·231	30·201	30·135	30·115	52·5	48·4
19	30·064	30·079	30·035	30·050	58·2	50·0	19	30·089	30·069	30·009	29·968	55·0	43·0
20	29·988	29·941	29·815	29·735	61·0	45·6	20	29·858	29·776	29·683	29·615	55·3	47·2
21	29·583	29·535	29·513	29·602	63·7	45·6	21	29·558	29·560	29·515	29·515	55·3	43·5
22	29·663	29·748	29·783	29·859	60·0	41·7	22	29·483	29·493	29·518	29·614	56·0	44·2
23	29·860	29·845	29·717	29·557	54·4	37·4	23	29·689	29·748	29·717	29·700	53·7	44·5
24	29·296	29·364	29·572	29·652	54·4	46·6	24	29·624	29·604	29·636	29·715	54·0	43·2
25	29·711	29·720	29·593	29·505	53·4	42·6	25	29·749	29·773	29·748	29·748	53·2	36·0
26	29·441	29·517	29·577	29·606	54·6	44·7	26	29·706	29·712	29·672	29·672	53·4	40·5
27	29·412	29·207	29·061	29·963	63·0	44·6	27	29·554	29·439	29·298	29·269	50·5	39·2
28	28·962	29·252	29·519	29·694	57·8	48·6	28	29·303	29·343	29·554	29·725	54·6	42·6
29	29·762	29·753	29·555	29·512	56·1	47·9	29	29·816	29·908	29·878	29·848	48·6	36·2
30	29·356	29·730	29·854	29·797	56·2	45·6	30	29·811	29·812	29·703	29·487	50·3	33·6

OCTOBER, 1871.

1	29·439	29·211	29·096	29·095	59·8	46·2	1	29·169	29·027	28·977	29·010	47·2	40·7
2	29·161	29·272	29·335	29·323	59·6	48·6	2	29·062	29·145	29·176	29·225	53·5	43·5
3	29·269	29·335	29·403	29·537	57·5	42·4	3	29·298	29·424	29·540	29·637	51·6	42·2
4	29·611	29·707	29·703	29·742	58·1	42·9	4	29·663	29·679	29·601	29·539	52·9	31·4
5	29·720	29·761	29·807	29·875	58·6	36·9	5	29·449	29·489	29·480	29·463	54·3	42·3
6	29·842	29·842	29·778	29·754	61·1	50·4	6	29·423	29·410	29·428	29·430	52·1	42·2
7	29·604	29·568	29·672	29·750	61·0	46·6	7	29·394	29·468	29·532	29·630	53·0	39·3
8	29·818	29·916	29·942	30·040	56·2	40·8	8	29·679	29·803	29·873	30·021	52·2	38·7
9	30·090	30·191	30·226	30·316	53·4	36·0	9	30·117	30·227	30·227	30·299	48·0	30·2
10	30·371	30·423	30·372	30·364	55·3	31·4	10	30·335	30·360	30·307	30·272	47·4	27·1
11	30·262	30·193	30·149	30·230	54·8	37·6	11	30·216	30·198	30·155	30·215	49·2	29·8
12	30·284	30·399	30·409	30·480	58·3	32·2	12	30·261	30·313	30·311	30·333	52·2	29·4
13	30·459	30·473	30·378	30·370	56·6	30·6	13	30·289	30·279	30·194	30·134	56·2	44·3
14	30·304	30·253	30·163	30·140	57·3	33·2	14	30·036	29·968	29·887	29·859	55·5	46·0
15	30·076	30·071	29·989	29·999	58·2	34·1	15	29·803	29·846	29·817	29·831	59·3	51·0
16	29·936	29·956	29·936	29·966	60·3	50·2	16	29·793	29·777	29·727	29·736	52·1	45·2
17	29·940	29·980	29·963	29·993	64·1	49·8	17	29·699	29·709	29·735	29·785	56·2	48·5
18	29·931	29·876	29·796	29·763	65·4	48·6	18	29·746	29·688	29·561	29·467	60·2	50·0
19	29·699	29·682	29·647	29·658	63·2	57·5	19	29·395	29·449	29·491	29·541	58·7	50·5
20	29·677	29·783	29·857	29·962	58·0	49·7	20	29·600	29·720	29·790	29·849	54·1	48·1
21	30·004	30·004	29·896	29·984	54·9	39·1	21	29·759	29·589	29·513	29·733	53·5	36·5
22	30·166	30·334	30·341	30·361	57·6	39·4	22	29·943	30·099	30·116	30·104	55·0	45·0
23	30·316	30·330	30·285	30·296	57·2	34·5	23	30·041	30·027	30·013	30·098	55·0	45·0
24	30·251	30·255	30·210	30·257	43·6	33·8	24	30·092	30·124	30·152	30·210	52·5	44·0
25	30·264	30·349	30·330	30·358	52·7	36·7	25	30·205	30·195	30·095	30·065	55·0	45·0
26	30·337	30·323	30·229	30·180	53·3	34·5	26	29·987	29·971	29·890	29·803	56·5	50·0
27	30·078	30·025	29·926	29·886	57·4	48·3	27	29·654	29·641	29·554	29·595	56·0	44·4
28	29·825	29·812	29·731	29·689	55·1	47·3	28	29·612	29·618	29·591	29·558	47·0	37·0
29	29·583	29·555	29·555	29·529	56·8	44·0	29	29·417	29·345	29·416	29·519	51·3	38·0
30	29·513	29·590	29·659	29·731	51·9	47·2	30	29·559	29·603	29·701	29·833	51·9	45·9
31	29·727	29·737	29·775	29·845	53·4	47·2	31	29·897	30·000	30·009	30·067	53·0	47·4

BAROMETER READINGS, &c.

NOVEMBER, 1871.

KEW.							GLASGOW.						
	Barometer.				Temperature.			Barometer.				Temperature.	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum	Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Maximum.	Minimum.
1	29·868	29·938	29·959	30·018	50·2	45·9	1	......	30·152	......	30·193	52·2	43·0
2	30·051	30·099	30·080	30·092	48·5	45·4	2	......	30·225	......	30·207	50·0	43·5
3	30·077	30·073	30·037	30·044	50·0	43·6	3	......	30·209	......	30·209	49·5	40·5
4	30·023	30·050	30·055	30·100	48·0	41·9	4	......	30·233	......	30·253	49·0	38·9
5	30·099	30·106	30·044	30·024	43·7	37·2	5	30·242	30·248	30·166	30·126	50·0	39·0
6	29·940	29·870	29·745	29·692	43·0	33·5	6	30·022	29·826	29·782	29·694	46·0	35·0
7	29·624	29·599	29·541	29·530	47·8	38·2	7	29·584	29·530	29·412	29·356	42·9	40·0
8	29·454	29·446	29·482	29·595	50·4	36·4	8	29·306	29·344	29·456	29·548	44·5	35·0
9	29·696	29·764	29·754	29·745	45·6	31·0	9	29·568	29·562	29·508	29·487	40·0	32·6
10	29·679	29·668	29·635	29·643	46·1	32·5	10	29·403	29·451	29·535	29·625	46·0	34·0
11	29·625	29·685	29·732	29·828	40·6	28·2	11	29·679	29·769	29·786	29·804	43·2	30·0
12	29·914	29·996	30·035	30·135	43·5	27·6	12	29·816	29·871	29·952	30·076	47·0	31·5
13	30·198	30·285	30·303	30·353	42·7	23·5	13	30·128	30·192	30·131	30·035	43·8	23·2
14	30·304	30·254	30·098	29·896	44·6	23·0	14	29·903	29·714	......	29·549	51·5	35·0
15	29·730	29·761	29·781	29·877	53·0	43·4	15	29·594	29·670	29·767	29·951	55·0	37·2
16	29·945	30·041	30·026	29·954	44·2	33·1	16	30·018	30·056	29·978	29·894	46·0	30·5
17	29·776	29·856	30·004	30·130	38·6	32·1	17	29·988	30·060	30·090	30·147	45·0	28·0
18	30·192	30·274	30·285	30·365	39·5	25·6	18	30·180	30·201	30·194	30·210	36·3	22·5
19	30·388	30·455	30·414	30·418	38·4	20·2	19	30·188	30·190	30·104	30·030	41·0	29·0
20	30·382	30·375	30·316	30·289	43·5	25·0	20	29·964	29·932	29·889	29·897	50·0	42·8
21	30·195	30·141	30·045	30·042	37·7	28·0	21	29·841	29·842	29·840	29·840	47·0	31·0
22	30·029	30·061	30·051	30·103	39·1	30·6	22	29·794	29·838	29·886	29·926	38·4	31·0
23	30·131	30·182	30·125	30·099	37·7	32·6	23	29·934	29·952	29·943	29·940	45·5	27·6
24	30·012	29·984	29·935	29·916	41·8	33·0	24	29·913	29·913	29·864	29·920	44·0	35·5
25	29·908	29·941	29·908	29·934	38·8	34·5	25	29·990	30·082	30·079	30·108	45·5	35·5
26	29·897	29·935	29·961	30·004	42·6	37·1	26	30·119	30·256	30·158	30·188	44·0	36·5
27	29·996	30·015	29·988	29·994	41·7	36·5	27	30·180	30·192	30·162	30·188	44·3	34·5
28	29·964	29·956	29·905	29·892	40·0	32·7	28	30·166	30·152	30·096	30·070	43·8	33·6
29	29·853	29·862	29·837	29·832	39·7	31·7	29	30·046	30·070	30·048	30·071	47·0	35·5
30	29·805	29·829	29·823	29·846	38·0	34·3	30	30·077	30·156	30·208	30·224	37·5	32·0

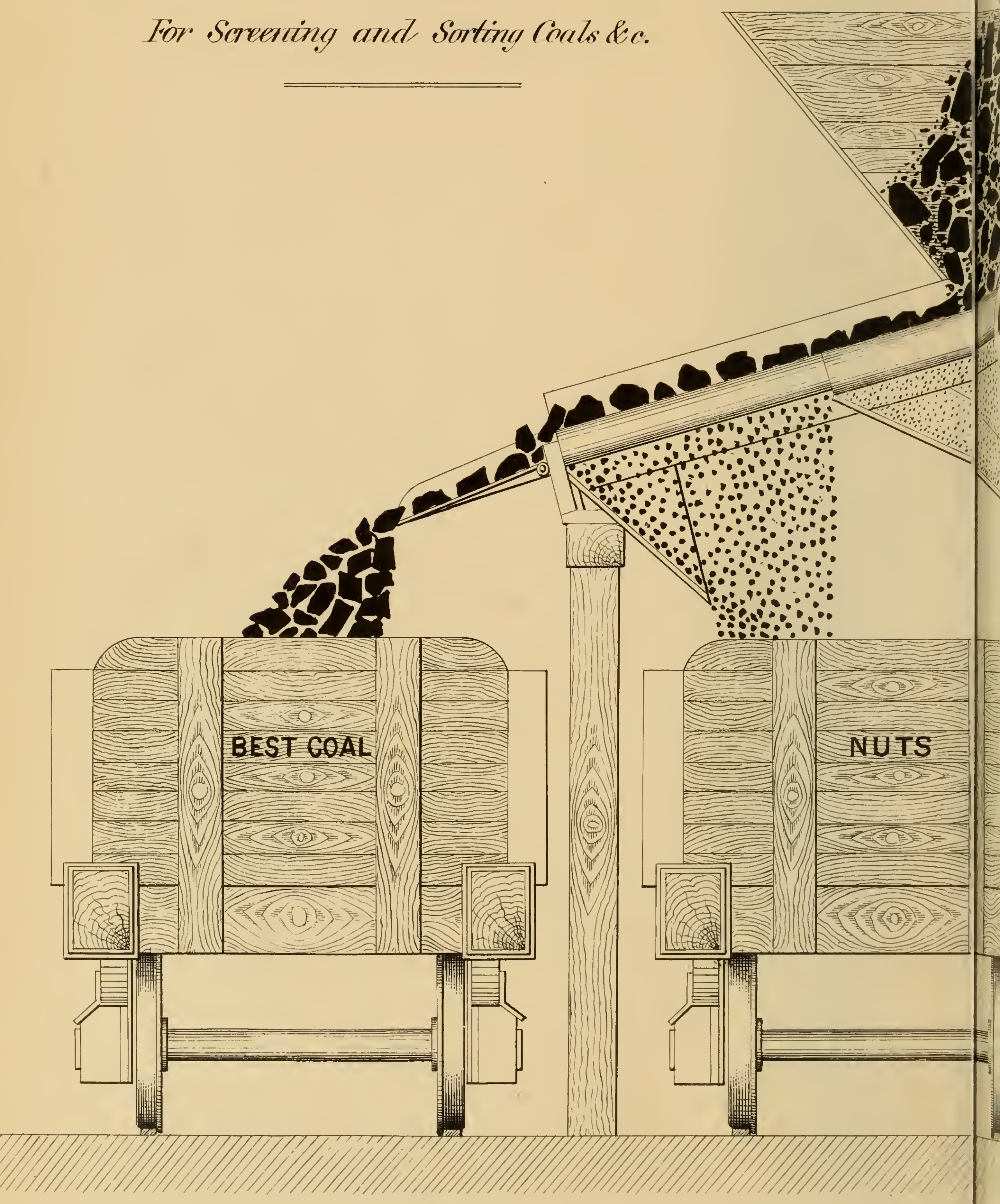
DECEMBER, 1871.

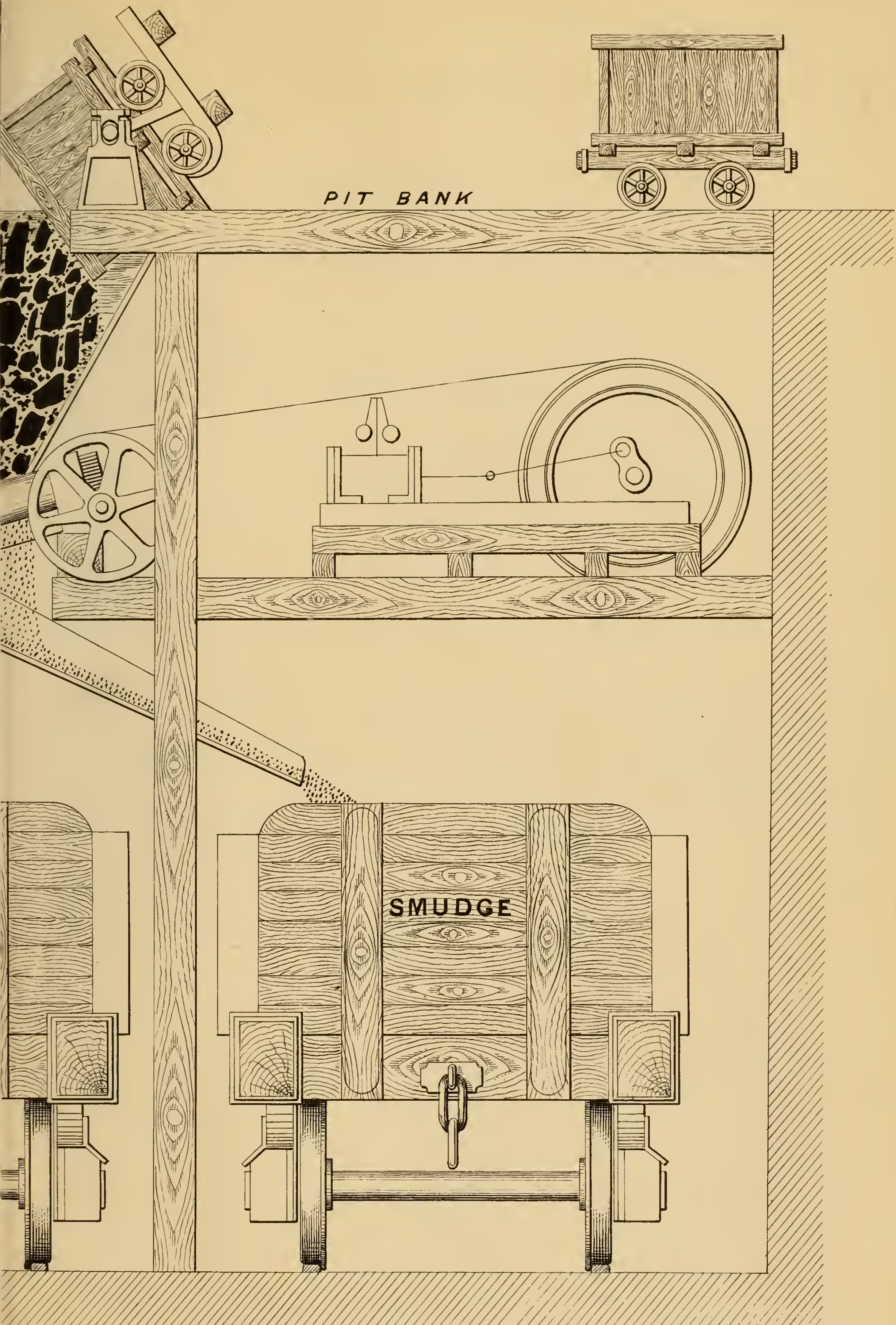
1	29·891	29·984	30·071	30·212	42·5	34·8	1	30·222	30·300	30·342	30·383	39·5	33·5
2	30·287	30·322	30·202	30·130	40·1	29·8	2	30·336	30·202	30·047	30·048	41·5	27·5
3	30·025	30·039	30·039	30·083	39·0	30·7	3	30·103	30·166	30·183	30·223	38·9	29·9
4	30·099	30·152	30·165	30·227	34·6	26·4	4	30·243	30·308	30·315	30·309	35·5	27·0
5	30·252	30·294	30·237	30·164	35·1	24·6	5	30·245	30·185	30·123	30·138	38·2	24·6
6	30·098	30·118	30·117	30·112	37·8	30·6	6	30·163	30·215	30·170	30·186	40·2	25·0
7	30·128	30·098	30·083	30·227	36·8	27·1	7	30·150	30·206	30·247	30·325	39·2	25·9
8	30·406	30·505	30·468	30·465	31·2	21·8	8	30·341	30·347	30·282	30·260	38·2	26·6
9	30·403	30·389	30·333	30·327	33·6	23·3	9	30·234	30·242	30·201	30·204	39·4	35·5
10	30·290	30·325	30·321	30·389	36·5	29·8	10	30·184	30·216	30·200	30·200	40·5	27·6
11	30·406	30·455	30·431	30·457	38·6	24·0	11	30·228	30·278	30·263	30·228	48·0	37·5
12	30·461	30·491	30·460	30·461	39·4	33·8	12	30·122	30·086	30·119	30·207	46·5	42·0
13	30·451	30·479	30·455	30·450	45·1	35·4	13	30·295	30·321	30·219	30·125	44·9	31·2
14	30·396	30·391	30·347	30·362	46·6	38·3	14	30·111	30·183	30·196	30·207	48·8	35·5
15	30·345	30·363	30·311	30·312	45·1	35·6	15	30·160	30·103	30·019	29·985	48·5	43·5
16	30·268	30·283	30·331	30·379	45·3	35·8	16	30·103	30·258	30·279	30·229	46·0	35·9
17	30·351	30·369	30·300	30·253	43·0	35·3	17	30·075	29·937	29·825	29·732	47·1	36·6
18	30·160	30·096	29·977	29·932	48·5	42·6	18	29·499	29·377	29·200	29·228	52·6	44·9
19	29·887	29·927	29·896	29·857	49·5	41·4	19	29·572	29·666	29·626	29·611	53·6	36·5
20	29·921	29·763	29·308	29·752	47·5	37·6	20	29·539	29·403	29·410	29·554	41·5	34·5
21	29·925	29·942	29·810	29·716	44·0	36·4	21	29·602	29·642	29·597	29·637	39·0	34·4
22	29·720	29·844	29·908	30·000	43·7	37·3	22	29·749	29·895	29·969	30·047	38·0	32·0
23	30·040	30·127	30·136	30·187	43·3	37·4	23	30·044	29·976	29·811	29·783	43·5	26·8
24	30·139	30·145	30·058	29·998	45·3	36·7	24	29·797	29·728	28·493	29·463	48·0	39·0
25	29·948	29·952	29·883	29·855	44·0	39·1	25	29·479	29·607	29·631	29·631	48·6	35·5
26	29·796	29·754	29·693	29·650	47·3	41·4	26	29·579	29·493	29·335	29·229	43·5	33·0
27	29·560	29·570	29·610	29·645	48·0	42·5	27	29·181	29·183	29·199	29·233	43·9	38·0
28	29·544	29·456	29·373	29·374	47·7	45·1	28	29·095	29·061	29·055	29·211	46·0	36·9
29	29·436	29·676	29·835	29·956	46·6	37·0	29	29·321	29·435	29·478	29·498	45·5	35·0
30	29·916	29·842	29·733	29·791	46·8	36·5	30	......	29·291	29·516	29·432	51·5	36·4
31	29·904	30·069	30·163	30·203	42·8	33·3	31	29·518	29·724	29·742	29·676	44·0	34·5

Hicks' Patent Screen,

With Revolving Bars,

For Screening and Sorting Coals &c.





Andʷ Reid, Newcastle

Hicks' Patent Screen

WITH REVOLVING BARS

For Screening and Sorting Coals &c.

FIG. 1.

GEARING COVERED BY DEAD-PLATE

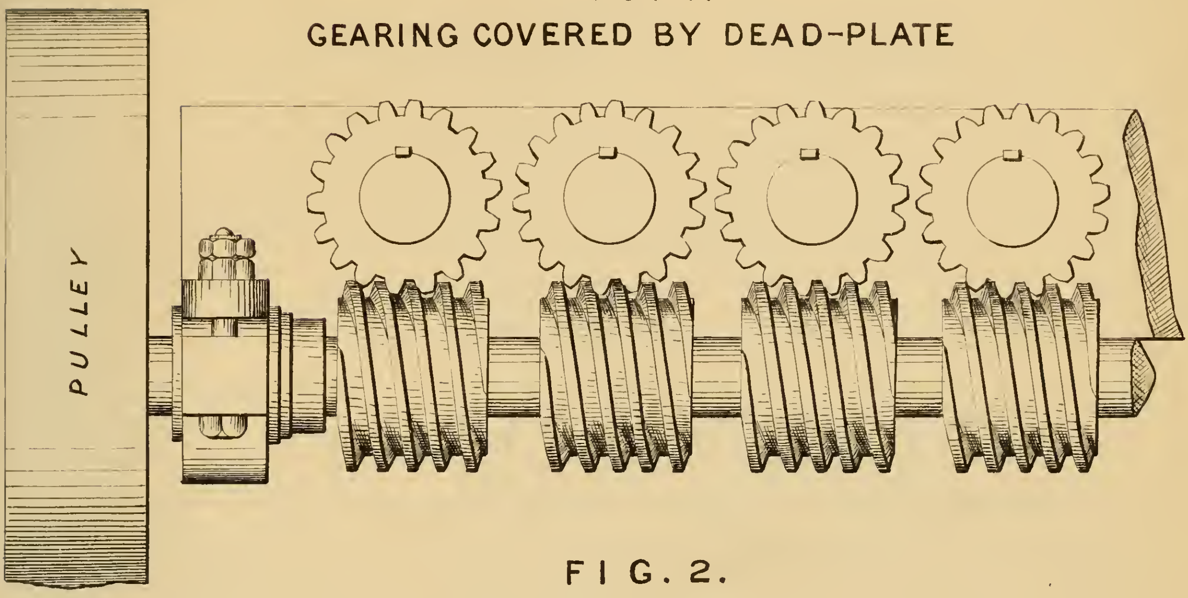


FIG. 2.

SECTION OF BARS

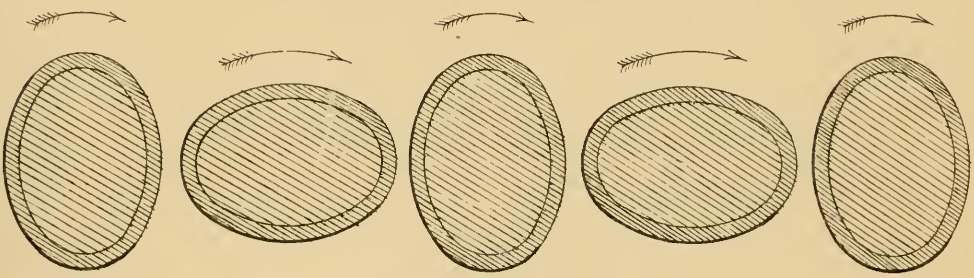
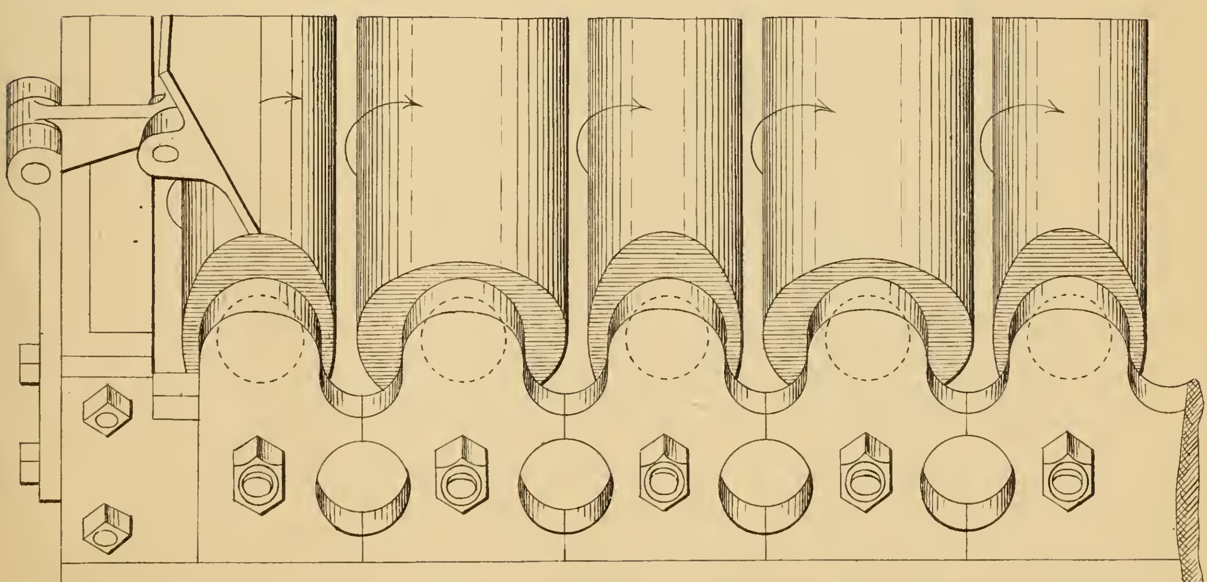


FIG. 3.

SCREEN FRAME – LOWER END



Scale 1½ inches = 1 foot.

Andw Reid, Newcastle

APPENDIX NO. II.

A DESCRIPTION OF PATENTS

CONNECTED WITH

MINING OPERATIONS,

TAKEN OUT BETWEEN JANUARY 1, 1871, AND DECEMBER 31, 1871.

BEING A CONTINUATION OF APPENDIX TO VOL. XX.

By the SECRETARY.

THE descriptions have been mostly given in the words of the patentee, all matter being excluded except that which is actually necessary to give some idea of the general principle involved. The exact details, if required, can readily be obtained from the Specifications. The patents are classified as before, viz. :—

1.—Lifting and winding, including safety-hooks.
2.—Mining, boring, and sinking.
3.—Pumping and modes of raising water.
4.—Ventilation.
5.—Safety-lamps and lighting mines.
6.—Coal cutting, getting, and breaking down.
7.—Explosive compounds.
8.—Miscellaneous.

FIRST DIVISION.

LIFTING AND WINDING, INCLUDING SAFETY-HOOKS.

1871. No. 1571. WALKER.

A safety apparatus composed of two links hinged together at the middle of their length, the lower parts of which project at an angle from each other, and are connected to the load to be raised, while the upper parts are held close together by a guard plate, through which they pass and hold the winding rope or chain between them. At the point beyond which the load must not be raised is a fixed beam with an aperture through which the upper end of the links pass until the guard plate bears against the under side of the beam. If the winding is continued beyond this point the links are drawn through the guard plate, whereby the lower ends of the links are brought close together while the upper parts are opened out, and thus release the winding rope, while at the same time the links take a bearing on the top of the fixed beam and thus sustain the load.

1871. No. 1481. Clarke and Hughes.

Improvements in safety apparatus to be connected with cages for mines and shafts. (No description given.)

SECOND DIVISION.

MINING, BORING, AND SINKING.

1871. No. 1072. Appleby.

Machinery for sinking bore holes, consisting of the use of steam, air, water, or other fluid for balancing the weight of the boring rods and apparatus for imparting a rotating, reciprocating, or combined action to the boring tool.

1871. No. 1612. Cowper.

Machinery for driving drifts. Consists in employing a series of jumpers or chisels separately actuated by means of compressed air or steam, and moved so as to produce parallel chases or grooves in the rock, the portions of the stone or rock between such grooves being subsequently broken off by hand or otherwise. Each chisel is fixed to the piston rod of an air or steam cylinder, all the cylinders being fixed either to a vibrating frame so as to cut rectilinear grooves, or to a revolving head so as to cut circular grooves.

1871. No. 2748. Dunn.

Improvements in boring and winding machinery for boring the first holes down through rocks, for searching for minerals, and for other purposes, and for winding, or raising and lowering the wire rope and pump within the hole or bore, for clearing it out when the boring rods are withdrawn therefrom from time to time, and, secondly, and especially, in a new construction and arrangement of the immediate actuating mechanism, for giving the vertical reciprocating or "jumping" action to the boring rods and tools of the said machine. Applicable also to other such like boring machines.

THIRD DIVISION.

PUMPING AND RAISING WATER.

1871. No. 88. Mills.

Improvements in pumps. Working barrel in the centre between two suction and discharge chambers, cast parallel in one piece with the barrel on each side. The whole three being closed in by ends and flanges, on which are bolted the suction chamber or well, at one end opening straight into the main suction pipe, a discharge chamber at the other.

1871. No. 247. Galloway and Beckwith.

Improvements in pumps. Constructing the valves of thin loose metal discs.

1871. No. 298. Walker.

Improvements in the construction of steam pumps. An arrangement whereby the piston of the steam cylinder acting at each end of its stroke against a pin fixed in a cored piston valve, and projecting into the cylinder, causes the said valve to slide in one direction or the other, and thus admit steam behind a solid piston fixed on the end of the spindle which carries the slide valve, and this steam acting against the solid piston changes the position of the slide valve immediately, and thus effects the return stroke of the steam piston, which then comes against the other pin and reverses the operation.

1871. No. 454. BUDENBERG.

Improvements in injectors. A chamber is situated between the steam nozzle and the back pressure valve. A vacuum is formed within the said chamber by blowing steam through it, and water will thereby be lifted and will rise into and remain at the same level in the said chamber and when the steam valve is opened the water will be injected into the boiler. In the second part of the invention a regulating chamber is employed, the said chamber communicating with the inlet pipe for water, and also with the part of the injector where the overflow pipe is fitted in ordinary injectors. The overflow passes into the said chamber and flows therefrom into the aforesaid inlet pipe. In a modification the inlet passage is contracted to suit the average force of the steam jet, and when the said inlet does not pass sufficient water, the deficiency is made up by water flowing from the said chamber, and on the said inlet passing too much water, the surplus flows into the said chamber and returns to the inlet pipe.

1871. No. 489. JACKSON.

The pump cylinder has a valve at the upper part, and the plunger is constructed of a hollow cylinder with two valves, one placed at the top of the suction pipe which extends nearly to the top of the inside of the plunger, the other being placed in the centre of the plunger on the top of a pipe which extends nearly to the bottom of the plunger.

1871. No. 531. GUTHRIE AND STEVENSON.

Constructing motive-power engines, pumps, and meters, by placing radially several cylinders, the outer end of each being closed, the inner ends open (open top cylinders) between two circular discs, each disc being supported by a shaft working in suitable bearings.

1871. No. 595. BUDENBERG.

Improvements in the valve seats of pumps, which are formed to carry their valves in a slightly conical cylinder.

1871. No. 646. MURPHY.

A rotatory pump, composed of two concentric cylinders, with an annular space between them, one cylinder carrying a projecting block or piston, and the other provided with stops or flaps to serve as obstructions for the steam or water to act upon.

1871. No. 807. PORTER.

An apparatus for raising water, which consists in substituting for the ordinary flap valve used in the cistern in connection with the ram, a self-acting valve opened and closed by the aid of a float and a tipping lever, and actuated by the filling and the emptying of the cistern.

1871. No. 906. JOHNSON.

Relates to a pump composed of an oscillating cylinder having a curved port face, which is supported by and rocks on slides in a to-and-fro curvilinear direction upon a corresponding curved bed, each curved surface containing inlet and outlet ports, which are caused to coincide in proper order by the oscillations of the cylinder.

1871. No. 1007. LAKE.

Raising water by buckets or scoops placed at the periphery of a drum, which is driven therefrom to the centre of the same. The drum is firmly secured to a shaft driven by a strap passing over a pulley fixed thereon. The case in which the drum is arranged is hermetically closed. The buckets have pointed edges and are constructed in such a manner that they do not exert any back pressure.

1871. No. 1199. BROWN.

Improvements in pumping. Consist in combining with the oscillating cylinder mounted on trunnions, chambers upon opposite sides, and between which the cylinder oscillates.

1871. No. 1368. WALKER.

Improvements in pumps. Consist in a steam cylinder having ordinary steam and eduction ports and fitted with a hollow piston made a little longer than the stroke. The valve chest is made cylindrical and fitted with two small pistons, between which is a slide valve for opening and closing communication between the exhaust passage and the ends of the steam cylinder. At or near each end of the valve chest is a drilled supply passage leading from the steam chest to the back of the small pistons respectively. There are also two supplementary exhaust ports leading from the spaces behind the small pistons to the central exhaust passage, but there is a break or interruption of continuity in these passages at or near the centre of the cylinder, past which point, the communication is only opened at a certain point of the stroke by means of one or the other of the two pockets formed in the outside of the steam piston, one at or near each other.

1871. No. 1376. REINLEIN.

A new pump for raising water, using steam directly, and without employing any mechanical agency, substituting for such agency that of atmospheric air, as an intermediate body between steam and water.

1871. No. 1576. EVANS AND EVANS.

The inventors employ a vertical shaft working in suitable bearings and set in motion by a lever or by means of wheel or other gearing. The pump is arranged horizontally and worked by means of a connecting rod from a crank, eccentric, or suitable equivalent fixed either at the bottom or some distance up a vertical shaft.

1871. No. 1740. RAMSBOTTOM.

A triplicate cylinder hydraulic engine; the cylinders are faced on each side and an orifice made through each, in which orifice is received an elongated valve divided by a midfeather and having six orifices, two for each cylinder, so as to admit and carry off water employed for actuating the said cylinders, which are each connected by a triplicate crank at equidistant centres.

1871. No. 2103. JONES.

Pumps in deep mines. This invention consists in effecting the working stroke of the plungers or pistons of pumps by the direct application thereto of hydraulic pressure conveyed thereto through pipes from an engine producing the said hydraulic pressure. The plunger or piston rod may for this purpose be made hollow, and a pressure pipe communicating with the supply pipe be made to enter the same so as to admit the water under pressure into the hollow. Or a rod or small plunger on the pump piston or plunger is made to work in a cylinder into which the water under pressure is admitted. Two-way reversing cocks are arranged to establish a communication alternately with the supply pipe and with an escape pipe.

1871. No. 2401. Barlow.

Constructing pumps, water meters, or engines of a hollow cylinder in which a smaller cylinder is made to revolve or is carried round so that the exterior surface of the smaller cylinder is always kept in contact with, or very close to the inner surface of the larger cylinder.

1871. No. 2507. Smith.

A pump for raising liquids within a hollow cylinder—a cylindrical barrel piston—with two thin broad vanes passed radially and longitudinally through its axis at right angles to each other, so as to slide in corresponding slots as the pressure acting pistons of the said barrel piston—is made to revolve close up to a quarter circular segment in the upper part of the outer casing, and a short distance into close cylindrical recesses in the end covers; with the pressure inlet duct and port entering into one side, and the outlet port and duct passing out on the other side of the actual acting part of the cylinder, made in the form of a concentric or segmental hollow cylinder, below the barrel of the piston, so that the projecting four ends of the said two sliding and acting pistons, as they come round to this large segmental part, fill and close the space while passing through it.

1871. No. 2794. Burr.

An improved steam pump. This invention relates to an apparatus for elevating water or propelling vessels, wherein the water is first drawn into a cylinder by means of a condensation of steam therein, and then expelled by a direct pressure of steam thereon.

1871. No. 2937. Newton.

An engine for raising water. This invention consists in the employment of two cylinders surmounting and opening into a channel-plate. In each of said cylinders is a piston connected through its rods and links to either end of a walking beam for producing a steady continuous discharge of water. By means of a peculiar arrangement of valves and tappets, steam is alternately let into each cylinder on top of the piston, forcing it down and expelling the water from its under side through the channel plate and discharge pipe.

1871. No. 2980. Okes.

The use of a multiplicity of independent engines and pumps in mines for draining purposes.

1871. No. 2985. Webb.

An improved injector for forcing water.

1871. No. 3189. Abel.

A rotary or centrifugal pump with a piston wheel revolving in a scroll cylinder or casing of ordinary construction, such piston wheel having hollow curved arms extending from a central chamber to a circular rim forming the periphery of the piston wheel; secondly, in combining with such centrifugal pump an auxiliary force or suction pump for priming or filling the pump when this is required for use as a suction pump.

FOURTH DIVISION.

VENTILATION.

1871. No. 915. THOMAS.

Improvements in ventilation. Consist of a belt or layer of pipes placed in the upcast shaft of mines, and of a series of jets or blowers for steam, or instead thereof or concurrently therewith for atmospheric air forced through them, to establish a current from downcast along the workings of the mine to the upcast shaft, the current carrying off the noxious vapours along with it.

1871. No. 1530. POUPARD AND THOMSON.

Improved means of ventilating tunnels. Atmospheric air is forced from a reservoir through pipes leading to different parts of a tunnel, the reservoir having a heating or cooling medium to act upon the air.

1871. No. 2626. ELLIS.

Machinery for forcing air, and consists of apparatus for the exhaustion, or exhaustion and forcing simultaneously, or alternately, of air or other gases, in which one cylinder is used revolving inside a larger, fixed eccentrically with the smaller one, with two or more fan blades or vanes, which, whilst revolving round a shaft concentric with the outer cylinder are driven by the inner one.

1871. No. 2647. SCOTT.

This invention consists in ventilating mines and tunnels through the agency of steam.

1871. No. 3339. TYLOR.

Improvements in apparatus for regulating the working and ventilating of mines, buildings, sewers, and underground workings, and for increasing the certainty, safety, healthiness, economy, and facility of conducting such operations, and for the distributing, regulating, measuring, and purifying of liquids and fluids, such as air, vapour of water, smoke and water, and in setting out and proportioning liquid and fluid passages and channels for irrigation and other purposes, and in the arrangements connected therewith.

1871. No. 3428. SCOTT.

Ventilating mines and tunnels. This invention refers to improvements upon the method for which provisional protection was granted to the inventor, dated October 5th, 1871, No. 2647, and consists in the use of a series of tubes and steam jets.

FIFTH DIVISION.

SAFETY-LAMPS.

1871. No. 1448. Plimsoll.

Providing a safety-lamp with an internal air chamber, through which the air must pass to the burner, so that when the air becomes explosive, it will, on entering the air chamber, immediately be ignited by the flame, explode, and extinguish the light. The explosion is limited to the air chamber by a wire gauze or perforated metal covering at the mouth of same.

1871. No. 1896. Irvine.

Safety-lamp. The invention consists in forming an inlet for air in the bottom of the flame chamber, such inlet being covered with wire gauze or other suitable permeable material, whilst the sides of the chamber are made close and impermeable, or nearly so.

1871. No. 2677. Yates.

Miners' lamps are constructed in such a manner that they cannot be opened by the miner without first extinguishing the light. This is effected by adapting to the body of the lamp a locking pin which will prevent the lower part from being unscrewed or detached from the upper part until such pin is drawn back.

1871. No. 3057. Plimsoll.

The improvements are applicable to the safety-lamp provisionally protected by the inventor on 31st May, 1871, No. 1448, and consist, 1st, in using in combination with the air chamber therein referred to, a slow threaded screw for connecting the oil box with the casing, whereby the light is extinguished before it can be withdrawn through want of air. Another improvement in this lamp consists in the use of two chimneys having an air space between them communicating with the air chamber above mentioned. The outer chimney serves to protect the inner one from sudden changes of temperature, and the light is not obstructed as when a gauze cover is used as in ordinary. The chimneys are protected by metal-ribs and wire netting on the exterior.

1871. No. 3181. Eley.

Improvements in miners' lamps. There is a double oil vessel, so that part of the supply shall be inside the lamp proper, and part outside, and connected so that the supply shall be equal to the demand, as long as the outer fountain contains any. The outer part is preferably semi-annular. Also a damper protects the wire gauze of safety lamps by suspending or supporting it near to the top; it may consist of a piece of metal, round, domed, or otherwise, and loosely fitting or filling up about ¾ths of the opening.

SIXTH DIVISION.

COAL-GETTING.

1871. No. 133. Williams.

Consists of a frame in which a sliding head is worked (backwards and forwards) thus operating on a screw block or blocks travelling on screws, so that the position of the cutting tool may be from to time adjusted in position so as to cut out square blocks of coal or mineral as required.

1871. No. 445. BALL.

The combination of a crane with a stretcher, bar, or tube, for the purpose of raising, lowering, and fixing rock drills and other similar mining, tunnelling, and quarrying implements in mines.

1871. No. 468. MACDERMOTT AND WILLIAMS.

Apparatus for boring, in which the particular points are, first, the use of automatic feed mechanism; second, the application of brake power to a nut through which a driving screw or spiral passes, so that the nut is made to revolve at a rate differing from that of the screw, which rate adjusts itself to the resistance the boring tool has to overcome; third, arrangements for seizing and letting go a boring bar; fourth, a "pneumatic holder," and expanding circular lewis for the purpose of retaining in position the boring machinery.

1871. No. 1471. ROTHERY AND ROTHERY.

Improvements in machinery for cutting coal. Consist in cutting a much narrower groove than has heretofore been found practicable by continuous revolving or rotatory cutters, whereby the power required is considerably reduced and less waste of the coal or other mineral is effected; facility is also afforded by means of the invention for cutting a groove to any desired depth without reference to the size or diameter of the rotatory cutter employed.

1871. No. 3004. WATTEEU.

Machinery for driving holes in rocks. Where a piston receiving reciprocating motion by compressed air or steam inside a cylinder carries a chisel for driving holes by concussion, the improvements consist, firstly, in a peculiar arrangement for actuating the slide valve of the cylinder. The slide valve is connected at its opposite ends to two pistons working in cylindrical holes in the slide valve box; the steam or air under pressure has access to both sides of the one piston, while the other piston (of smaller diameter than the first) is acted on the one side only by the steam or air under pressure, the other side being open to the atmosphere. An escape valve actuated by a trigger and a tappet on the piston rod of the machine allows the steam or air to escape from the one side of the first slide valve piston at the end of the back stroke of the machine, whereby the one motion of the slide valve is effected for producing the forward stroke of the chisel. On the closing of the said valve an equilibrium of pressure is re-established on the said slide valve piston so as to produce the return stroke of the slide valve. The driving chisel is rotated at each stroke by a pawl and ratchet-wheel actuated by a bar receiving a rocking motion from two small pistons in cylinders into which the steam or air under pressure is admitted alternately.

1871. No. 3270. HASELTINE.

An improved method of excavating rocks. The object of this invention is to effect the removal of a large quantity of material in a short time and with a saving of labour and expense, and this object is accomplished by first boring all the drill holes, then filling them with suitable material, and then gradually shattering the rock in successive lifts by repeated explosions until it is torn away to the bottom of the drill holes.

1871. No. 3438. ALEXANDER.

Machinery for getting coal. The working parts are carried on a horizontal iron frame running on four wheels, which rest on a pair of rails, and are by preference quite plain or unflanged, displacement off the rails being prevented by pins or lugs fixed to or formed on the frame and projecting down beside the rails. The cutting of the mineral is effected by a modification of the well-known arrangement of cutters on an endless chain, distended by a gib projecting out horizontally from one side of the frame.

SEVENTH DIVISION.

EXPLOSIVE COMPOUNDS.

1871. No. 311. SMITH.

Improvements in the manufacture of gunpowder or explosive compounds of the character described in the Specification of a Patent granted to Ernest Dronke, dated 11th April, 1864, No. 900.

1871. No. 921. SPRENGEL.

The preparation of explosive compounds, based on the well-known principle of keeping separate the oxidising from the combustible agent until such time as the effect of their chemical combination is required.

1871. No. 776. WELCH.

Apparatus for generating a current of electricity for discharging fuses for mining and other purposes. It consists of an arrangement of a permanent magnet and soft iron cores furnished with coils of insulated wire, a soft iron armature being provided, which is capable of being removed and replaced, and a current of electricity induced by means of a combination of mechanism acted upon at pleasure by a key.

1871. No. 1326. MUSCHAMP.

An improved explosive substance, manufactured by a novel treatment of lignine or woody fibre. The first operation is the disintegration of the wood by means of a chipping machine. The sap and mineral salts must then be extracted ; to accomplish this object the wood is boiled for about six hours in a suitable boiler by boiling with a solution of caustic soda or other alkaline liquid. The fibre is next thoroughly washed with pure water. It is then removed to a beater, and when reduced to the proper shortness it is put into a strainer. It is then removed into a heated room and dried. The fibres are then steeped in nitric and sulphuric acids, and allowed to remain in the acids for about 24 hours ; it is then washed.

1871. No. 2045. JAMES.

In manufacturing fuses, a machine similar to the ordinary circular braiding machine is used. To this braiding machine is applied a self-acting feed apparatus for supplying the gunpowder to the interior of the braid, which forms the cover of the fuse.

1871. No. 2335. KLERITJ.

A cartridge for blasting purposes, made of much cheaper materials than those ordinarily employed, and so constructed that the same effect is produced as in other cartridges, while about one-fourth only of the powder usually employed is required for this cartridge.

1871. No. 2642. SPRENGEL.

The preparation of explosive compounds. This invention relates partly to the preparation and use of what the inventor calls safety explosive compounds, and is based on the well-known principle of keeping separate the oxidising from the combustible agent, until such time as the effect of their chemical combination is required.

1871. No. 2715. WATTEEU.

For blasting marble or granite quarries and other hard substances, the following ingredients are mixed together, 12·5 parts by weight of sawdust, 67·5 parts by weight of nitrate of potash, and 20 parts by weight of powdered sulphur. For blasting limestone and chalk quarries and coal or other substances of a comparatively soft nature, the following are mixed together, 11 parts by weight of sawdust, 51·50 parts of nitrate of potash, 16 parts of nitrate of soda, 1·5 parts of coal or lignite powder, and 20 parts of sublimed sulphur.

EIGHTH DIVISION.

MISCELLANEOUS.

1871. No. 283. CRISPIN.

Machinery for washing and dressing the debris from lead mines. Consists of an arrangement of a perforated or wire cylinder and a close cylinder, which are caused to rotate, the debris being passed through the same successively and washed by means of water during the rotation, the slime resulting from the operation being allowed to flow from the end of the close cylinder into a suitable launder. The perforated or wire cylinder is fed by means of an arrangement consisting of an endless chain or belt, which is placed in a trough and passed over grooved pulleys at the respective ends of the trough.

1871. No. 302. CHAMBERS AND ELTON.

Preparing artificial fuel by mixing disintegrated coal dust, refuse anthracite, or bituminous coal, coke breese with chalk lime combined with creosote, naphthaline, or other dead oils.

1871. No. 310. TATE.

Raising and lowering the gates at pit mouths by applying to the end of the winding axis a worm wheel working into a horizontal toothed wheel, the axis of which actuates two sets of rods, levers, and segments connected with the pit gates, which are alternately raised and lowered as the skips rise and descend from the mouth of the pit.

1871. No. 884. BRYDON AND KENDALL.

Improvements in signal indicators, which consist of a drum with seven or other number of sides, upon which figures or letters are made that show through a hole in the case of the drum, which can be turned backwards and forwards to bring any required side before the hole ; there are also pins or spindles in the drum, which come against a spring lever hammer, each pin or spindle in passing giving one stroke on a bell. All are connected by wire rope to move together, and are brought back to show "no signal" by a weight.

1871. No. 905. TREGAY.

Apparatus for stamping ores. An arrangement by which the "grateway" or discharge-way through which the pulverized substances pass can be extended around both the compass or sides and angles of the "cover" or coffer, so that the whole, or as much as may be desired, of the compass or sides and angles of the coffer can be used as grateway or discharge-way by setting back the stanchions of the foot piece.

1871. No. 1204. HOPKINSON.

Machinery for elevating and weighing coal. Consists of a series of buckets attached to an endless chain working over a tumbler propelled by steam, delivering the coal into a shoot. A weighing machine may be fixed in the shoot.

1871. No. 1292. HOPKINSON.

Weighing coal. This mechanism is intended to be connected to or to stand upon the weighbridge of the weighing machine. It consists of a wheel arrangement with arms or divisions radiating from the axle at right angles, for a portion of the distance towards the circumference and then recurved or bent back for the remainder, so that when one division is filled with coal or other material, the centre of gravity is on the delivery side, which is then weighted, and by lifting a catch, revolution occurs and the coal is delivered into a ship.

1871. No. 2498. HARDY AND HARRISON.

Improvements in picks. For this purpose a metallic socket of suitable form to cover and protect the ends of the shafts or handles is provided with a projection or tenor fitted to enter a mortise formed in the tool for which it is designed.

1871. No. 2527. HARDY AND STAYNER.

Improved method for shafting picks. This invention consists in the employment of a metallic collar or circlet, which is fixed upon the shaft of any tool, upon which collar is formed a cushion for the reception of the eye of the tool, such cushion being of any elastic or semi-elastic material, or material more yielding or softer than that of which the eye of the tool is composed.

1871. No. 2743. BRECKON AND JOY.

Screening and cleaning coals by machinery driven by steam, water, or other convenient power in a manner that greatly reduces the manual labour of moving the coals over the surface of the screen, whilst, at the same time, it enables the screen man to pick out pieces of stone, foul coal, and other objectionable substances more expeditiously and effectually than by the screens and appliances now in use.

INAUGURATION

OF THE

NEWCASTLE COLLEGE OF PHYSICAL SCIENCE.

SPEECH BY THE VERY REV. THE DEAN OF DURHAM.

SIR W. G. ARMSTRONG, MY LORDS, LADIES, AND GENTLEMEN,—The occasion on which we meet to-day, and on which we are grateful for the attendance of many whose presence is an indication of the interest felt by a large part of the North of England in our undertaking, is one both of satisfaction and hope to Newcastle and the neighbourhood. It is a matter of satisfaction and gratitude that we should be able to announce to you that in little more than six months after the scheme for a college of scientific teaching—with a special view to the educational wants of the North of England—was proposed, we are enabled by the zeal of those who have taken a wise view of the interests of all classes in this matter, to begin an effective course of instruction; and it is a further gratification that our plan has been understood and responded to by those for whom it was designed, so that we are not in the rather awkward position which has sometimes been the lot of similar institutions at their commencement, of having professors but no pupils, but are able to give our professors plenty of work, and with that work the opportunity (which is all they require) of showing what our institution can do. In saying this, we willingly admit that our institution is still only in the very earliest state of its existence—not, perhaps, that mere protoplasm of which we have heard so much of late, for it has at least got four legs to run upon—but still very far from having its full body of scientific, and still more of literary teaching. We believe, indeed, that the education which we are enabled to offer to our pupils is a sound one, but we are far from putting it forward as complete, and we trust that in a very few years we may be able to render it more worthy both of this great town and of the Northern University, of which we hope it may form so important a part. It is in accordance, then, with this idea that we have made a good start —but very little more—that I shall endeavour, my lords, ladies and gentlemen, to place before you to-day something of an estimate of the place which physical science ought to hold in a good education for the upper and middle classes, particularly in a part of England whose wants are somewhat peculiar. I shall have to speak mainly, of course, of physical science; but you will see at once that it is impossible to do this without some reference to other great branches of education. I shall try to show both what purely scientific study can do for us, and what it cannot; that, for a body of men employed in the work of developing the resources of the country, this knowledge is a matter of simple necessity, and that it is scarcely less so to those who wish to develope the resources of their own minds, and to estimate, even if we cannot wholly understand, the true place which man holds in that universe of which he is in some sense the master, in others but a feeble atom; but in which he is at least always, in Bacon's words, "Man the servant and interpreter of nature." I shall try to show that this want—felt far less deeply in past times—cannot be put aside or denied in this inquiring and material age, in which men are no longer able to take a part in its struggle and to grapple with its deeper problems, unless they add to their other acquirements, however varied they may be, some knowledge of that vast and often perplexing material world, of which great men of past generations were content to be wholly ignorant. And still, while saying this, I mean to press upon you that physical science ought never to stand alone as an instrument of education, and that those who are its most ardent votaries need the most to be reminded, that there are other great lines of study by which it must be supplemented, if the physical inquirer desires to gain that completeness of thought and knowledge without which a man will be brilliant but never wise, and the neglect of which has led to the greatest failures of science, and (we may add) of moral and political knowledge. The wisdom of the old Greeks expressed this quaintly when it said that "a man should be a perfect square and no mistake," and a German poet, who was a great master of life, has expressed the same thought in language which may thus be translated :—

> Ever aim at completeness, and if thou canst not attain it,
> Be as a ministering limb, joined to a body complete.

You will see then, I think, at once, that though I am going to-day to uphold strongly the study of physical science as an instrument of education, I am not disposed in doing so to run down what is called the old system of education, though I certainly believe that in past days, and even at present, it is carried out in a rather one-sided and ridiculous fashion. The English education for the upper and middle classes, and this was till thirty years ago the only education existing in the country—for you may remember what sounds now an astonishing fact, that Mr. Burke, about eighty years ago, estimated the whole number of readers in England at only 80,000—may be generally described as conducted almost entirely by teaching language and by teaching mathematics, or rather about nine-tenths of the boys in our higher schools profess to learn a certain amount of Latin and Greek, and the remaining tenth are (in the opinion of the rest of their schoolfellows) eccentric creatures who have an unnatural liking for mathematics—a study which it is, or was, contrived to make so repulsive to the nature of boys that I could give you a list, if I chose, of some of the most eminent statesmen, and the best scholars, too, in the country, who were all "plucked" for their "little go," because they could never pass the "Ass's Bridge." Now, far be it from me to disparage language as a great instrument of education. If I wanted to define a good education, I should say that it consisted in two things: first, in drawing out and disciplining the powers of the mind so as to make it do our bidding in our coming life; and, at the same time, in imparting, along with this power, a considerable amount of valuable information. Now, on the first of these points—the discipline of the mind—a great deal may be said for the study of language. Language rightly used is a kind of mental logic. It trains the young mind unconsciously in accuracy of thought and in power of expression; and, as we get older, its higher studies introduce us to those great works of the Greeks and Romans, which, for beauty both of thought and words, have never been equalled. I will even venture, in passing, to say a word for those despised Latin verses at which everyone now-a-days has a shot, which are supposed by many to be the *reductio ad absurdum* of the system, but real skill in which indicates, I think, no small command of expression. I remember that, when at one of those Commissions which sat lately on public schools, it was proposed to give up writing Latin verses, a friend of mine exclaimed, with vehemence, "Abandon Latin verses! why, you will be destroying one of the great solaces of life;" and although this may provoke a smile, yet if you understand his remark to apply to the soothing power of ancient poetry generally—which a boy of talent in this direction appreciates all the more by the habit of composing in verse—to the deep love for Homer and Virgil, for Æschylus and Sophocles, which the old system of education, taken at its best, imparts, I do not think he was so very far wrong. We must add to this a real love for history, which the study of the great ancient historians and political philosophers—by far our best models in this respect—imparts; and I must venture to think that that very acute man, Mr. Cobden, made a great slip when he declared that there was more to be learnt from one copy of the "Times" than from what he called "all the works of Thucydides" (though, by-the-bye, Thucydides wrote only one work), and I could quote against him one who is no depreciator of modern study, Mr. John Stuart Mill, who said that he forgave the University of Oxford many of its shortcomings because it had kept alive the study of the three greatest works ever written—the Ethics, Rhetoric, and Politics of Aristotle. In fact, gentlemen, if I may sum up, in one sentence, my brief pleading for a study of ancient literature rightly sought, the greatest English minds, and the best character of English thought, have been formed since the Reformation by two things—the Bible and the study of the Classics; and those who believe that this character, and all the history which has been its result, have been inferior to none in Europe, will never be disposed to give up the great works of the old world as one most powerful instrument of education. At the same time, I cannot deny that these studies have been, and still are, carried on in an absurdly exclusive fashion. In the first place, even as regards the cleverest boys, our present system almost entirely ignores a knowledge of their own literature and history. I know the plausible answer which will be given: that, in proportion as a boy is clever in Latin and Greek, you will find that he works up his knowledge of English for himself; but this is by no means universally true. I should like to ask the boys who know their Thucydides best at school, how many of them afterwards have mastered Clarendon or Gibbon? and I have sometimes been present at lectures, given to young men at training schools, on Shakspeare and Chaucer, which it would have been of the highest advantage, for all their lives, to clever boys at a public school to hear, but I never heard of anything of the kind being given. Then, again, the plan of teaching nothing but languages is a great sacrifice of the many to the few. The mass of boys and of young men care simply nothing for Latin and Greek. They go through them as a sort of treadmill; and just as a treadmill certainly makes a man aware that he has legs, and must use them whether he likes it or not, so his Latin drill makes him know that he has got something like a mind which he can use afterwards if he chooses; but it is hardly too much to say that to nine out of ten boys their Latin and Greek has no earthly use but this, and that, as soon as they have escaped from it, they never open a Greek or a Latin book again. Now, I am not so Utopian as to think that we shall make all boys fond of study if we simply change the subjects which we teach. I am afraid it will still be found that "Dunce the second reigns like Dunce the first" in the laboratory as well as the schoolroom. Nor must we forget that as a nation we have a very strong sense of the importance of that occupation which our neighbours have borrowed one word to express when they call it "Le Sport;" and of the truth of the old proverb that "all work and no play makes Jack a dull boy." But I believe, in the first place, that there is certainly something of a natural aptitude in these matters, and that a very much larger scope should be allowed, or rather invented, in education, for applying a boy's talents to that work for which nature meant them. There never was a greater scapegrace at school than the famous Lord Clive, who was known there for nothing but robbing his neighbours' hen-roosts, and climbing the church steeple to carry off the weather-cock, and yet this boy had talents for command and administration, which, after all manner of failure and two attempts at suicide, made him the founder of our great Indian empire. So it may be with many a lad here or elsewhere. A calculation was made by Mr. Forster lately—and I believe quite a sound one—that not more than three boys in a hundred are boys of exceptional ability. Grant it; but how many boys of talent would that give us every year, if we could judiciously apply the capacities of the 20,000 boys always requiring education in Newcastle to their right objects. The fact is, that in all our schools, public or other, we need far more division of work, or what our neighbours in France and Germany call a "Bifurcation" in this matter. We may give our boys pretty much the same general education up to thirteen or fourteen, but then let them "bifurcate." Some keep to their languages, and others go off to a school of natural science, according to the boys' strong propensity or the insight of an able master shall direct; and then, just let me make this further remark, which I should apply to all boys whatever—whether dull or clever—in our present great schools—I mean as to our want of arrangement of time in the whole course of our education. Is it not, indeed, ludicrous and self-condemnatory that all boys should have their time so badly distributed during the teaching years of their life that they should actually pass from six years old to eighteen or nineteen in mastering, some well, some wretchedly ill, two languages, together with a smattering of French, which they may pick up from their sister's governesses? In this matter I entirely agree with Professor Huxley. Something—I don't mean anything very deep—of those wonders of nature which a child sees around him, and which the childish mind is naturally very curious to know about, ought to be taught to every child, boy or girl, early. "The Germans," says the Professor, "have a good name for this—Erd-Kunde, or earth knowledge,"—that is, a general knowledge of what is on the earth, in it, and about it. If any one who has any experience of the ways of young children will call to mind their questions, he will find that they soon come under this head of earth knowledge. The child asks, what is the moon, and why does it shine? what is the water, and where does it run? what is the wind? or how do you get the water up in this pump? And if not snubbed and stunted by being told not to ask foolish questions, there is no limit to the intellectual craving of a young child, nor any bounds to the slow but solid accretion of knowledge and development of the thinking faculty in this way, but all would at least get to know *something* about it. I don't say that all boys will take to this equally; but I certainly think it ludicrous that any of us should (and I am afraid we most of us do, in fact) grow up in entire ignorance of our bodies, and of everything we see or handle—that a man of the highest education, if he was to become by accident a settler in a new country, should know nothing of the construction of a pump or a fire-engine; or if he was making a voyage to Australia, and be ignorant of the simplest rules of navigation, should not know how he is to shape his course, or what is the use of the compass or the meaning of the equator. In attempting to state to you to-day what appear to me to be the advantages of such a scientific education as we propose to offer, I have wished in the first place to give a short sketch of the system under which most of us here have been taught, and of its strong and weak side, partly because I should be equally ungrateful and untrue to myself, if I did not speak warmly of the charms of that refined classical teaching, which is the parent of so much that is excellent, and partly because it will always remain very imperfect unless we supplement it by a real knowledge of things—*i.e.*, of nature, and of all the wonders which a study of nature discloses. I now turn to those studies of physical science of which we to-day inaugurate the beginning; and I ask you to consider how these may be used to supplement the great defects I have spoken of, and how, even without a knowledge of literature, they may give us a real valuable training. Let me begin by a word or two of apology. I am unwilling in a mixed assembly like this to enter at any great detail on subjects which must be to many necessarily dry—especially as it is only two or three days since I read the following account of a lecture like the present in a leading newspaper:—"A Lecture on Chemistry," it says, "is a very dull affair without explosions, electric shocks, liquefactions, crystallizations, depositions, and volatilizations." I shall, therefore, eschew, as much as possible, both hard names and a long discussion; but I suppose I may venture to say this much at starting—that when we hear of this "dull affair," the study of physical science, we have all a sort of notion that what is meant is astronomy, chemistry, mechanics, anatomy and physiology, geology and palæontology. Now, what is it which makes the study of all these subjects an entirely different thing from these other great literary studies of which I have just been speaking? It is, in one word—first, that the things themselves are different; and next, that the method in which we study them is different. In studying language, we are studying words and thoughts, and in studying history we are studying records; but in studying the great facts of nature we are studying actual things—things which for the most part we must understand by seeing them, by handling them, and by touching them—things which are at first matters of experiment, and, when finally discovered, matters of certainty. Here, then, is that original difference between the objects of literary and scientific study which leads to such an entirely different method in pursuing the studies themselves. And, accordingly, I should say generally, that the advantage to the mind of an education in physical science is (1) that it trains us to habits of close observation, of inquiry, of induction, and of verification; (2) that in doing this it brings us into close contact with the actual facts of nature; (3) that it has a direct bearing on our business in life, to an extent which is hardly the case with any other study. Let me try to expand these statements. The first of these facts I will try to impress upon you by a short account of the principles on which all scientific discovery has been founded. I suppose we have most of us read or heard that our great countryman, Lord Bacon, was the founder of modern philosophy and of positive science, and that he founded it by exploding the notions of the ancients, and particularly the logic of Aristotle, and establishing what is called the inductive philosophy, which means pretty much inquiry by means of constant experiment, in its place. Now, it is not necessary to inquire here how much the ancients did or did not know about physical science. Being great lovers of abstract truth, there is no doubt that they cared comparatively little for the utility, the practical side of scientific truths; nor had they as yet the means of testing them fully by experiment. Still we must not undervalue them. Archimedes, at all events, managed to set the Roman ships on fire by his burning glasses, not to speak of his theory of the lever, which, I believe, was the foundation of statics till the time of Newton; and, though no doubt many of these theories are absurd, yet you must remember that our own age is not yet quite so enlightened as to despise the wisdom of the great men of old. I think I could match the folly of the ancients even from some of their ablest detractors. Take the following for instance from a really great man, Roger Bacon, who wished all the works of Aristotle were burned, but who himself propounds the following scientific account of dragons:—"One of the best modes," he says, "for prolonging life is by the flesh of a dragon. It should be prepared as the Ethiopians prepare it. Where there are good flying dragons they have an art of drawing them out of their dens, and have bridles and saddles in readiness, and they ride on them, and make them bound about in a violent manner, that the toughness of their flesh may be reduced as boars are hunted, and bulls are baited, before they are killed for eating." However, leaving alone for the present the defence of the ancients, let us see what were those great principles of induction which Lord Bacon discovered, and which justly entitle him to be called the man "whose prophetic genius enabled him to delineate a science which had not yet begun to exist." The principle of induction, regarded simply as a method of inquiry, is merely that of believing in no statement whatever unless it has been previously tested by certain rules of observation and experience, and Bacon's great merit is that he first, and in a way which may really be called prophetic, laid down these rules, and thus systematized the method of discovery. It is simply in this method, and in nothing else, that Bacon's merit consists. But it is an immense merit; for it is neither more nor less than a discovery of the laws of thought as applicable to all scientific subjects. It was doing for science almost exactly what Aristotle had done for reasoning, laying down the rules according to which every process must be conducted. This is not the time to show you how Aristotle did this in the syllogism; but, in Bacon's case, the merit of his system of induction was, not simply that he said, "You must proceed by experiment"—others had done that before—but that he taught men how to do so; and in his "prerogative instances," as he quaintly calls them, he gives us a list of nearly every kind of experiment which can be applied in the investigation of scientific truth. It is perfectly true that men were at work on Bacon's own principles already, that Copernicus had a century before exploded the belief that the earth was the centre of the universe, and that Kepler and Galileo, in Bacon's own day, were demonstrating the motions of the sun and the planets, and in Kepler's own quaint language, "were sending into the field a reserve of new physical forces for the rout and dispersion of the veterans." It is even possible that Bacon knew nothing of these great discoveries himself. But this does not touch his merit; by that wonderful combination of sagacity with imagination which has made him the very Shakspeare of philosophy, and which has even in our day given some vogue to a theory that he was himself the author of many of Shakspeare's plays—he foresaw and laid down for ever the laws of all scientific inquiry. At the same time it is not to be disputed that the merit of Bacon's great work has often been denied. Our foreign friends have been particularly jealous of it, and a lively writer, the Count Joseph de Maistre, has argued, not without some plausibility, that Aristotle had himself distinctly laid down the principle of induction for the discovery of scientific truth. The most curious instance of this attack has, however, been Lord Macaulay's, and as it will have the advantage of illustrating what I have said about Bacon's real merit, I will give it you, especially as, in the words of a well-known joke—"It will do Bacon no harm, and may amuse you." Lord Macaulay, beginning with the slashing onset with which he usually attacks the favourite beliefs of mankind, and of philosophers in particular, tells us that "the inductive method has been practised ever since the beginning of the world by every human being. It is practised," he says, "by the most ignorant clown, by the most thoughtless school-boy, by the very child at the breast. It leads the clown to conclude that if he sows barley he shall not reap wheat. The very infant, we imagine, is led by induction to expect milk from his mother or nurse, and none from its father." He then proceeds as follows:—"Bacon's Analysis of Induction is but an analysis of what we are all doing from morning to night, and continue to do even in our dreams. A plain man finds his stomach out of order. He never heard Lord Bacon's name; but he proceeds in strict concordance with the rules in the 'Novum Organon,' and satisfies himself that minced pies have done the mischief. 'I ate minced pies,' he says, 'on Monday, and was kept awake by indigestion at night.' This is the *comparantia instantiarum ad intellectum convenientium.* 'I did not eat any on Tuesday, and I was quite well.' This is the *comparantia instantiarum quæ natura data privantur, i.e.,* of negative instances. 'But on Christmas-day I almost dined on them, and was dangerously ill.' This is the *comparantia instantiarum secundum magus et minus.* 'It cannot have been the brandy which I took with them, for I have drunk brandy for years without being the worse for it.' This is the *dejectio naturarum.* Our invalid then proceeds to what Bacon calls the vintage, and concludes that 'mince-pies do not agree with him.'" Now, I need not enter upon a very serious refutation of this lively passage, but will merely say that to attack Bacon for reducing into system the rules on which men are constantly reasoning instinctively without knowing it, is merely like attacking Columbus for showing how men could all make an egg stand upright, or discover America, if they only knew the way. Macaulay's argument is very much the same as that which Dr. Watt brought against Aristotle's logic, "that God had not been so unkind to man as merely to make him a two-legged animal, and left it to Aristotle to make him rational;" and it may be safely left to Hallam's grave remark, that "those who object to the importance of Bacon's precepts in philosophy, that mankind have practised, many of them immemorially, rather confirm their utility than take off from their originality; for every logical method is built on the common faculties of mankind, which have been exercised since the Creation." Bacon's bequest to philosophy was, in fact, then simply this:—"Study the rules"—these prerogative instances which I have spoken of—which "I give you for the discovery of natural truth, and you will find that these will guide you to a certainty," &c. And to a certainty they *have* guided. The habit of testing everything by the variety of experiments which Bacon described, has been the origin of that scientific certainty which has led to all the great practical discoveries of modern philosophy. Here then, in this great principle, seems to me to lie in germ the real strength of physical science—that it is a method of mental training by careful and constant experiment, and that it gives us results which are absolutely *certain;* and here it is that in some respects it surpasses any other method. In *some* respects, not in *all;* for I cannot think that the study of the material world, sublime as it is, is so noble or so interesting to man as the study of his own mind, or of his wonderful history and destiny. I cannot think that even Newton—even though

> "When Nature and Nature's laws lay hid in night,
> God said, Let Newton be, and all was light,"

has been so great a benefactor to mankind as Shakspeare. This, however, is a mere matter of opinion; and I admit that the magnificent certainties of the great law of gravitation, with its endless applications to the sun, the moon, the planets, the earth, the sea; or again, that the laws of electricity, as they were gradually discovered by Dufay and

Franklin, and worked into clearness by Oersted and Davy and Faraday; or, again, the wonderful developments of mechanical power begun twenty centuries ago by Archimedes, re-discovered by Galileo, advanced by the great Pascal, carried out by Huyghens and D'Alembert; or, again, the theory of heat and steam, which we owe, first, to R. Boyle and Dalton, and by which our own great James Watt has almost changed the laws of time and space,—I say, I cannot deny that in the vast effects, the certainty, the boundless applicability of these great physical discoveries, they are at once so astounding and so magnificent, that they may well elevate the minds of the students of natural philosophy to enthusiasm, and make them believe that no other study can equal one which can thus make "earth, sea, and sky the vassals of man's will." Such, then, I hold are the first advantages of the student of physical science—it trains him to those rules of induction, of experiment, and of verification, by which all great discoveries have been made; it makes him insensibly familiar with the course of inquiry by which he may, in very truth, "interrogate nature," and it gives him a large knowledge of that immense world of material truth which nature can reveal. And in saying this, I have almost anticipated the second advantage which I attributed to this study that, in a manner quite different from any other, it brings us into such direct contact with facts. Other sciences, mathematics for example, which are so essential both as a basis for nearly all physical inquiry, and also as a means for proving and completing discoveries (as in fact Newton's great discoveries needed a whole century of mathematical thought to complete them), mathematics, I say, are simply a source of argument and of deduction. The mathematician starts with a few obvious propositions, and the rest of his work consists in drawing deductions from these. This training is, I need not say, infinitely valuable; and it is especially valuable in physical science on this account—not merely because it so wonderfully strengthens the attention and enables men to carry in their heads long trains of argument and of calculation—but because it shows that physical science rests upon the highest laws of reasoning, and that we can only master it by vigorous and systematic training. But then, this training once gone through, the student of physical science must (as it were) grapple with nature itself, and very little he will ever know of it unless he can do its work for himself, with his own hands and with his own eyes. And this, by the testimony of all scientific men, it is important to impress upon the minds of students at the very outset. They will never know anything of chemistry unless they do good work in the laboratory; it is only by examining for themselves fossil after fossil that they can know anything of the structure of the earth; only by experiments with the platinum wire and with the prism by which you can understand any of these wonderful discoveries about the rays of the sun which were first taught us by Sir J. Herschel; only by experiments of your own in electricity that you will be able to admire the wonderful genius of Faraday. 3. One other point only, which, perhaps, I ought not to have reserved for the end: It is the practical value of these studies, and their bearing on some of the most important professions in the country—it is, how far will they assist you in "getting on." Now, I assure you I am far from undervaluing this very telling, and eminently modern and perfectly English, view of the question. "Getting on" is said to be the Englishman's idea of Paradise, and it is not a bad idea of it either, if we only understand "getting on" to mean in goodness, and not merely in money. I am quite aware—and I do not at all blame it—that we might preach for ever to you to take a scientific view of your profession, and not a single man would study a single second (and I am not sure that he would be wrong) if he thought that by doing so he would be left behind in the race of life. I am not indeed sure, I may say in passing, that this eagerness for immediate results does not sometimes overshoot its mark; and I suspect that often the man who has spent two or three "unproductive" years in gaining a really profound acquaintance with his profession, whether as a lawyer, an engineer, or a clergyman, in the end turns out the more successful man. For example, to put it in the most practical shape—and one which some of you may one day remember, especially if you neglect it—a man who has made a large fortune goes, we will say when he is about fifty, into Parliament. Now, do you suppose it makes no difference to such a man whether he goes with the reputation of being a really scientific man, who can throw light upon those scientific questions which now so constantly engage public attention, or with the character of a man who has got on simply by natural energy aided by the rule of thumb? I am speaking with no disrespect of the latter class, whose energy I honour, and who would be the first to admit what I am urging. But I will venture to say that a man who (if he will permit me to allude to him) were to go into Parliament like our president, with the reputation of a really scientific discoverer, would be listened to on every question in which he was interested, while the man who went by the fortunate accident of a few lucky hits would by no means find himself so much in his element. But we need not take a case so far off. I speak to practical men, and will be judged by them;

and I ask them whether an engineer can go very far without a good knowledge of mechanics—and whether he is not, at all events, better for an acquaintance with mathematics, which is the groundwork of all high mechanics. Whether he has not to make his experiments daily on the strength and properties of metals, or on the application of geometry to construction? Or, again, whether a sound knowledge of hydraulics will not help him—whether a scientific knowledge of the fluidity and gravity of liquid bodies will not enable him to use their pressure as a motive power on the bottoms and sides of vessels—or in the case of confined fluids and liquids in pit shafts? or what can a man do in these days without chemistry? without having studied the action of the two great agents—light and heat—the principles of decomposing or of composing, and the atomic proportions of almost every substance in the universe? If you will just remember that whether a man is working in the mineral, the vegetable, or the animal kingdom, he must refer to chemistry at every turn, that it is through its assistance that in minerals he must detect the characteristic of each specimen, and must purify, and separate, and prepare them for the use of man; that in vegetables, again, and agricultural produce, it is only by chemistry that he can determine their most nutritious qualities, and the soils best suited for their growth, I believe that you will see in these—and they are but a very few of the thousand instances of the application of scientific knowledge to labour and enterprise—that there is no kind of science which will not be of daily value in the work of mining and engineering. But, sir, why do I dwell upon a point so obvious? It is not that you have any doubt upon the question. It is quite true that, in the North of England, especially, the native energy and talent of our great miners and engineers, aided by unequalled natural advantages, have placed us almost at the head of the enterprise of the world. But you are too sagacious, gentlemen, not to be aware that in days of keen struggle we shall not hold our own unless we can enlist the most tried and educated workmen on our side. You are too well aware that in many branches of labour, of everything especially which has to do with art, of the composition of colours for instance, we are surpassed by foreigners already, and I will add, to take a more limited, though still a just view of the question, you, whose children are about to embark on those great professions, know that their best chance, and far their noblest course, will be by attaining a thorough scientific mastery of the work they will have to do in life. Sir, I fear that I may have detained the meeting too long already. I know I have had to discourse on a subject with most parts of which I am very imperfectly acquainted, and in the presence of men who, if they were not kindly disposed to me, would feel how superficially I have discharged a work which was not my own seeking, and which I undertook only in obedience to the kind wishes of others. I must say, however, that on more than one account I undertook it with zeal, almost with enthusiasm. I have seen, or fancied I have seen, ever since I have been in the North of England, that there is room here for a higher education,—yes, I may say, a University education of a different sort, but certainly not less manly or real than what is now given at our older Universities. I trust to-day may be the beginning of an attempt to establish something of this kind at Newcastle. You have heard what my notions of a good education are, and that they are far from being limited to the teaching of Physical Science. I hope that Literature will soon take its place in your classes, and there is nothing which would more rejoice me than to see the early foundation of a Professorship of English History and of Political Economy. Let me say it rests mainly with the people of the good town of Newcastle to determine whether there shall be established here a more complete form of education than we can offer to-day for your young men, and I certainly will not exclude young ladies also. If you will make some little exertion and sacrifice to obtain for two or three years, from 16 or 17 to 19 or 20, such an education as I hope we can offer you, I am sure that such a branch of university teaching established here would at once be a benefit to the town, and to the large, active, and intelligent district of which this is the centre.

INDEX TO VOL. XXI.

Accounts, viii., x., xii.

Adams, Thomas, On a new form of direct acting spring safety valve, 285.

Address (inaugural) by E. F. Boyd (joint meeting), 223.

Address On the inauguration of the College of Physical Science, by the Dean of Durham, end of vol.

Advertisement, xlv.

Air-compressing machinery at Ryhope Colliery. Description of, by W. N. Taylor, 73.—Table of experiments, 78. —Discussed, 81.

Plates.
14. Section of the air-compressing cylinder.—15. Inlet and outlet valves for compressing cylinder.—16. General arrangement of the air-compressing cylinders. — 17. General arrangement of the steam engine and air-compressor.—18. Compressed-air and tail-rope system.—19. Air engine.—20. Section of level in under-sea coal workings at Ryhope. —21. Section of cylinder of the underground winding engine.—22. Diagrams—Steam engine, air compressor, and interior engine.

Air compression—Application of machinery in the collieries of Sars Longchamps and Bouvy, by M. L. Cornet (translated by John Daglish), 199.—Discussed, 217.

Plate.
33. Fig. 1. Section of coal-field ; fig. 2. Horizontal plan, showing the general position of the galleries.

Air-vessels in pumping engines and the means of replenishing them, by R. B. Sanderson, 115.—Discussed, 154.

Alteration of Rule 4, 82.

Analyses. Cockfield Dyke stone, 254. —Weardale limestone, 265.—Ferryhill limestone, 265. — Raisby Hill limestone, 266, 267, 269, 270. — Magnesian limestone, 266. — Harmby limestone, 266. — Pickering Oolitic limestone, 266.—Weardale limestone, 266, Boldron limestone, 267, 269.— Merrybent limestone, 267, 269. — Forcett limestone, 269.

Annesley Colliery, working by Longwall at, by Henry Lewis, 3.

APPENDIX, No. 1, Barometer and thermometer readings for 1871, end of vol.

Appendix, No. 2, Patents connected with mining operations, end of vol.

Appendix to rules, xlii.

Bainbridge, E., On the difference between the statical and dynamical pressure of water columns in lifting sets, 49.

Barometer and thermometer readings for 1871.—Appendix, No. 1, with diagrams.

Boring of pit shafts in Belgium discussed, 9.

Boyd, E. F., Inaugural address at joint meeting, 223.

Carboniferous limestone of South Durham and North Yorkshire, by W. Cockburn, 257.

Plates.
34. Geological Map of Yorkshire.— 35. Section of limestone, Stanhope Quarry ; Section of bysalt belonging to Ord and Maddison.—36. Section of great limestone at Frosterly Quarries.—37. Section of limestone, Raisby Hill Low Quarry ; Section of great limestone at Broadwood Quarries.—38. Average section of Forcett Limestone Quarry ; Section of great limestone at Duckett Hill Quarries.—39. Section of limestone, Raisby Hill High Quarry ; Section of great limestone at Duchess Quarries, Merrybent.—40. General section of strata between Carrs Cragg and High Force.—41. Plan of Broadwood Limestone Quarry.

Coals, On a new and improved method of screening and loading, by Robert Miller, 295.

Cockburn, W., On the carboniferous limestone of South Durham and North Yorkshire, 257.

Coleman, I. J., On mineral oil as a lubricant for machinery.

College of Physical Science, Desirability of electing the professors hon. members, 47, 82.—Inaugural Address by the Dean, end of vol.

Cornet, M. L., On the application of machines worked by compressed air in the collieries of Sars-Longchamps and Bouvy, translated by John Daglish, 199.

Cornish pumping engine at Settlingstones, paper on, by F. W. Hall, 59.

Council, report of, v.

Councillor, election of, in place of Mr. Hosking, deceased, 83.

Counterbalancing of engines, discussed, 218.

Daglish, John, translation of paper by M. L. Cornet, on the application of machines worked by compressed air in the collieries of Sars-Longchamps and Bouvy, 199.

Dean of Durham, Address on the Inauguration of the College of Physical Science, end of vol.

Difference between the statical and dynamical pressure of water columns in lifting sets, by E. Bainbridge, 49.

Education of the mining engineer, by John Young, 21.—Discussed, 33, 40.—Note by Ralph Moore, 38.

Election of a Councillor in place of Mr. Hosking, deceased, 83.

Experiments on rivetting with drilled and punched holes and hand and power rivetting, 67.

Fowler, George, On the scroll drum, 85.

General statement of account, xii.

Geology, in some of its practical aspects, by Dr. David Page, LL.D., 241.

Hall, F. W., On the Cornish pumping engine at Settlingstones, 59.

Hicks' apparatus for screening and loading coals, described by Robert Miller, 295.

Honorary members, xiv.

Howard, W. F., Ten years' mineral statistics of the United Kingdom, 161.

Inauguration of the College of Physical Science, Address by the Dean of Durham, end of vol.

Incorporation of the Institute suggested, 72.—Discussed, 289.

Joint meeting with the Scottish and South Lancashire Engineers, 221.—Inaugural Address, 223.

Kinneil Iron Works, arrangement of machinery for pumping water in dip workings, by Ralph Moore, 159.

Lewis, Henry, On working coal by longwall at Annesley Colliery, 3.

Life Member, xiv.

Lifting sets, On the difference between the statical and dynamical pressure of water columns in, by E. Bainbridge, 49.

Literary and Philosophical Society, thanks to, for use of rooms, 82.

Loading and screening coals, new method of, by Robert Miller, 295.

Longwall method of working coal at Annesley Colliery, by H. Lewis, 3.—Pillars to divide districts, 5.—Timber, 6.—Length of stalls, 7.—Discussed, 104.

Plates.

1, 2. Plans of working by Longwall.—3. Section of the top hard seam at Annesley.—25. Section of the goaf and main road.—26. Side view of gate road.

MEMBERS: Patrons, xiii.—Honorary, xiv.—Life, xiv.—Officers, xv.—Ordinary, xvi.—Students, xxxiv.—Subscribing collieries, xxxvii.

Miller, Robert, On a new and improved method of loading and screening coals, 295.

Mineral oil as a lubricant for machinery, by I. J. Coleman, 291.—Table of experiments, 293.

Mineral statistics of the United Kingdom, 1861 to 1870, by W. F. Howard, 161.

Moore, Ralph, Note on Mr Young's paper on the education of the mining engineer, 38.—Arrangement of machinery for pumping water in dip workings at the Kinneil Iron Works, 159.

Officers, xv.

Page, Dr. David, On Geology in some of its practical aspects, 241.

Patrons, xiii.

Professors of the College of Physical Science, desirability of electing them hon. members, 47, 82.

Pumping, Paper on the difference between the statical and dynamical pressure of water columns in lifting sets, by E. Bainbridge, 49.—Discussed, 91.

Plates.
4. Bucket door piece, &c. — 5 to 9. Diagrams showing varying pressure of water in one stroke.—10. Indicator diagram and diagrams showing position of gauge in forcing and lifting sets.

Pumping engine at Settlingstones, paper on, by F. W. Hall, 59.—Discussed, 64, 91.

Plates.
11, 12. Indicator diagrams.

Pumping engines, air vessels in, and the means of replenishing them, by R. B Sanderson, 115.—Discussed, 154.

Plates.
27, 28. Illustrating the paper.—29. Arrangement at the Gateshead pumping stations.

Pumping water, by W. Waller (2nd paper), 123.—Discussed, 154.

Plates.
30. Diagram showing oscillations of pressure in the mains.—31. Diagrams.

Pumping water in dip workings at the Kinneil Iron Works; arrangement of machinery described by Ralph Moore, 159.

Plates.
32. Plan, &c., of Dook pumping arrangements.

REPORTS: Council, v.—On rivetting experiments, 67.

Reprinting of volumes out of print discussed, 288.

Rivetting: Report upon experiments with drilled and punched holes and hand and power rivetting, 67.

Plate.
13. Diagram illustrating the report.

Roberts, Thomas, On the teeth of wheels, 271.

Rule 4 altered, 82.

Rules, xxxviii.

Ryhope Colliery, description of air-compressing machinery at, by W. N. Taylor, 73.

Safety-valve (spring), new form of direct acting, by Thomas Adams, 285,

Plate.
46. Section of valve.

Sanderson, R. B., On air-vessels in pumping engines and the means of replenishing them, 115.

Screening and loading coals, a new and improved method, by Robert Miller, 295.

Plates.
47. View of Hick's apparatus.—48. Section of bars, view of lower end of screen frame.

Scroll drum, paper on, by Geo. Fowler, 85.

Plates.
23, 24. Diagrams.

Smyth, W.W., paper on boring pit-shafts in Belgium discussed, 9.

Students, xxxiv.

Subscribing collieries, xxxvii.

Subscriptions, Treasurer in account, viii.

Taylor, W. N., description of air-compressing machinery at Ryhope Colliery, 73.

Teeth of wheels, an improved method of approximating to the true epicycloidal forms by circular arcs, by Thomas Roberts, 271.

Plates.
42, 43, 44, 45. Illustrating the paper.

Ten years' mineral statistics of the United Kingdom, 1861 to 1870, by W. F. Howard, 161.

Treasurer in account with subscriptions, viii.

Treasurer in account with Institute, x.

Waller, W., On pumping (2nd paper), 123.

Wheels, teeth of, by Thomas Roberts, 271.

Young, John, On the education of the mining engineer, 21.

Newcastle-upon-Tyne: A. REID, Printing Court Buildings, Akenside Hill.